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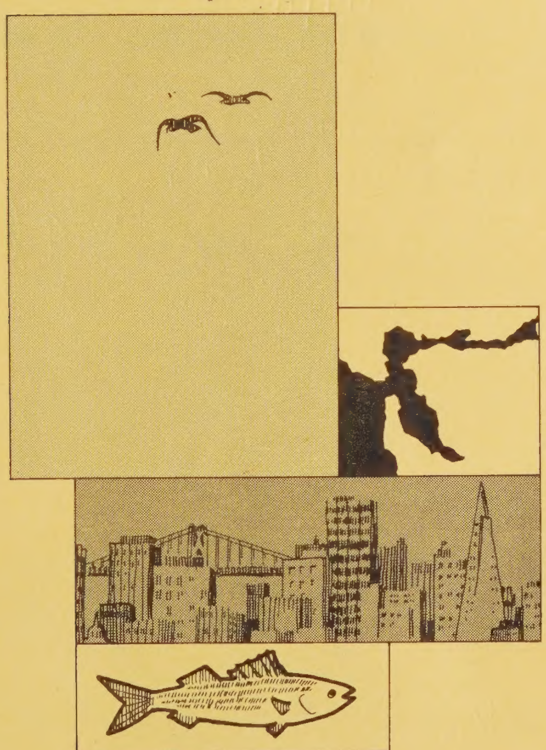
Appendix O

APPENDIX O

Regional Wetlands Plan for Urban Runoff Treatment

San Francisco Bay Area Environmental Management Plan

April 1983



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This plan was prepared by the Association of Bay Area Governments with a grant and other assistance from the Environmental Protection Agency, in cooperation with Bay Area Air Pollution Control District, Metropolitan Transportation Commission, San Francisco Bay Regional Water Quality Control Board and Counties of the Bay Area.

ABAG

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Appendix O

APPENDIX O

SAN FRANCISCO BAY AREA WATER QUALITY MANAGEMENT PROGRAM

REGIONAL WETLANDS PLAN FOR URBAN RUNOFF TREATMENT FROM THE 1982-83 WATER QUALITY PLANNING PROGRAM

Volume I: PLAN AND AMENDMENTS TO THE ENVIRONMENTAL MANAGEMENT PLAN

Volume II: TECHNICAL MATERIALS

April 1983

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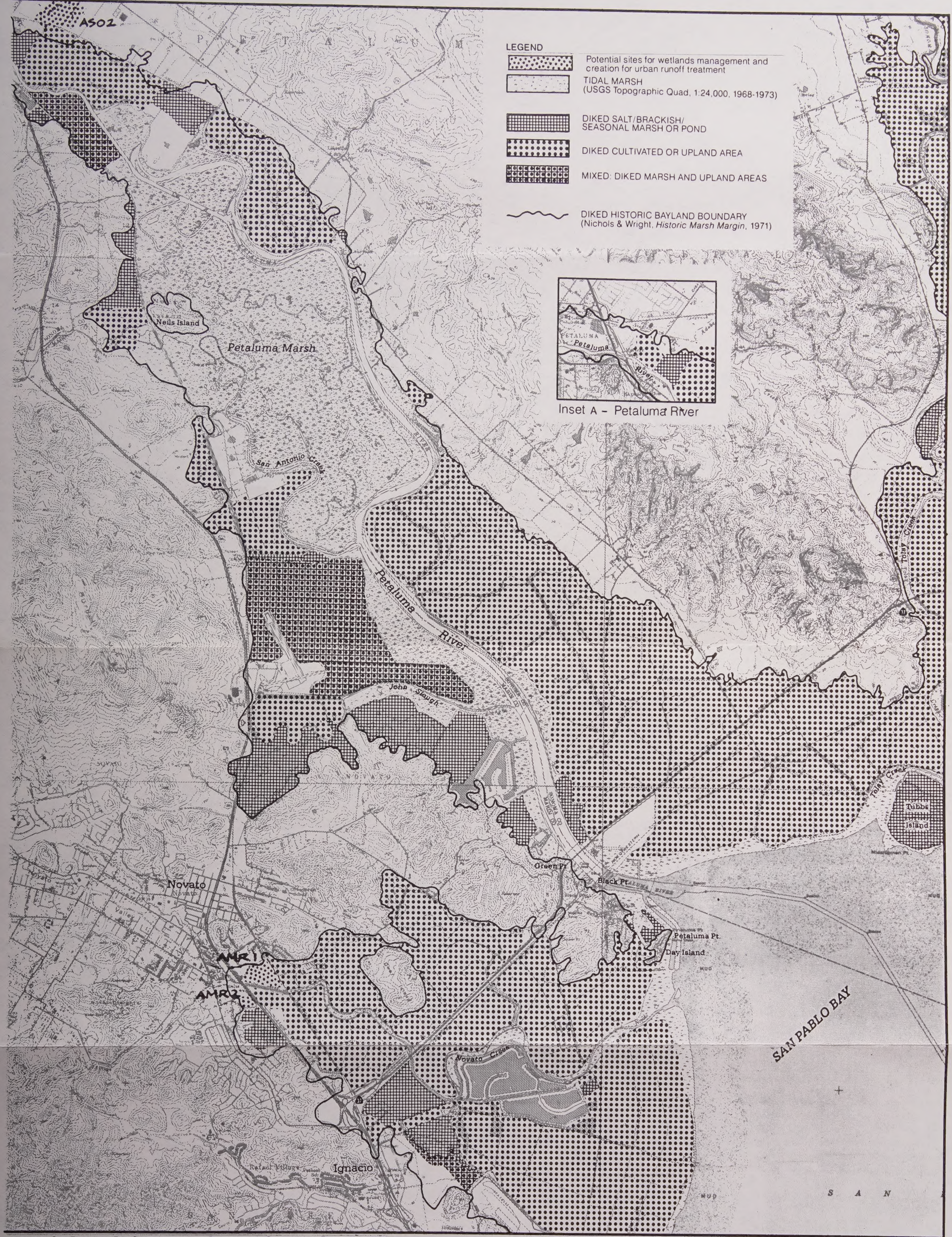
See Inset A
for continuation.



ap source: San Francisco Bay Conservation and Development Commission, December 1982

ABAG Regional Wetlands Program for Urban Runoff Treatment

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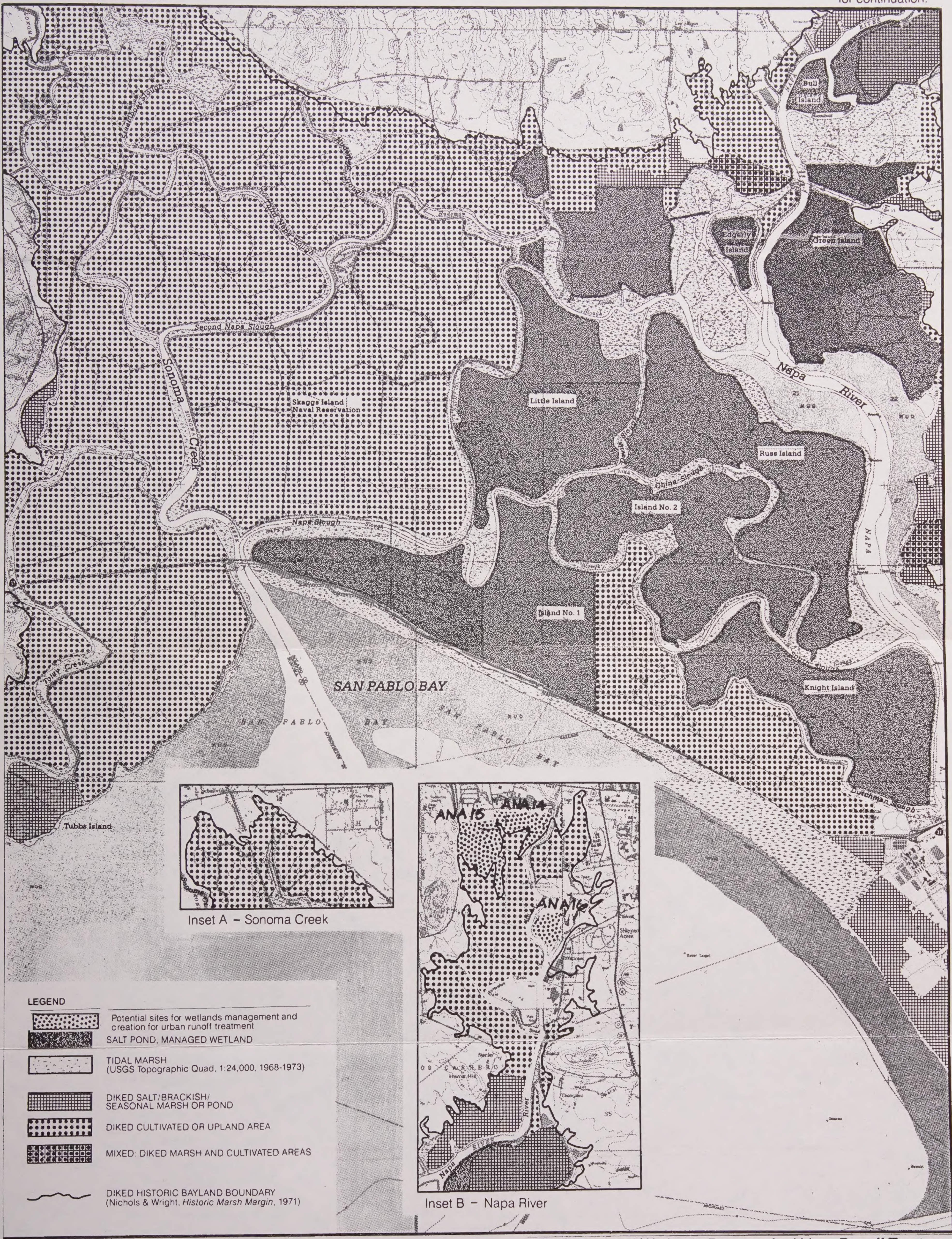
1 .5 0 KILOMETER 1
NORTH

MAP 11.
Petaluma River

See Inset A
for continuation.

See Inset B
for continuation.



Map source: San Francisco Bay Conservation and Development Commission, December 1982

ABAG Regional Wetlands Program for Urban Runoff Treatment

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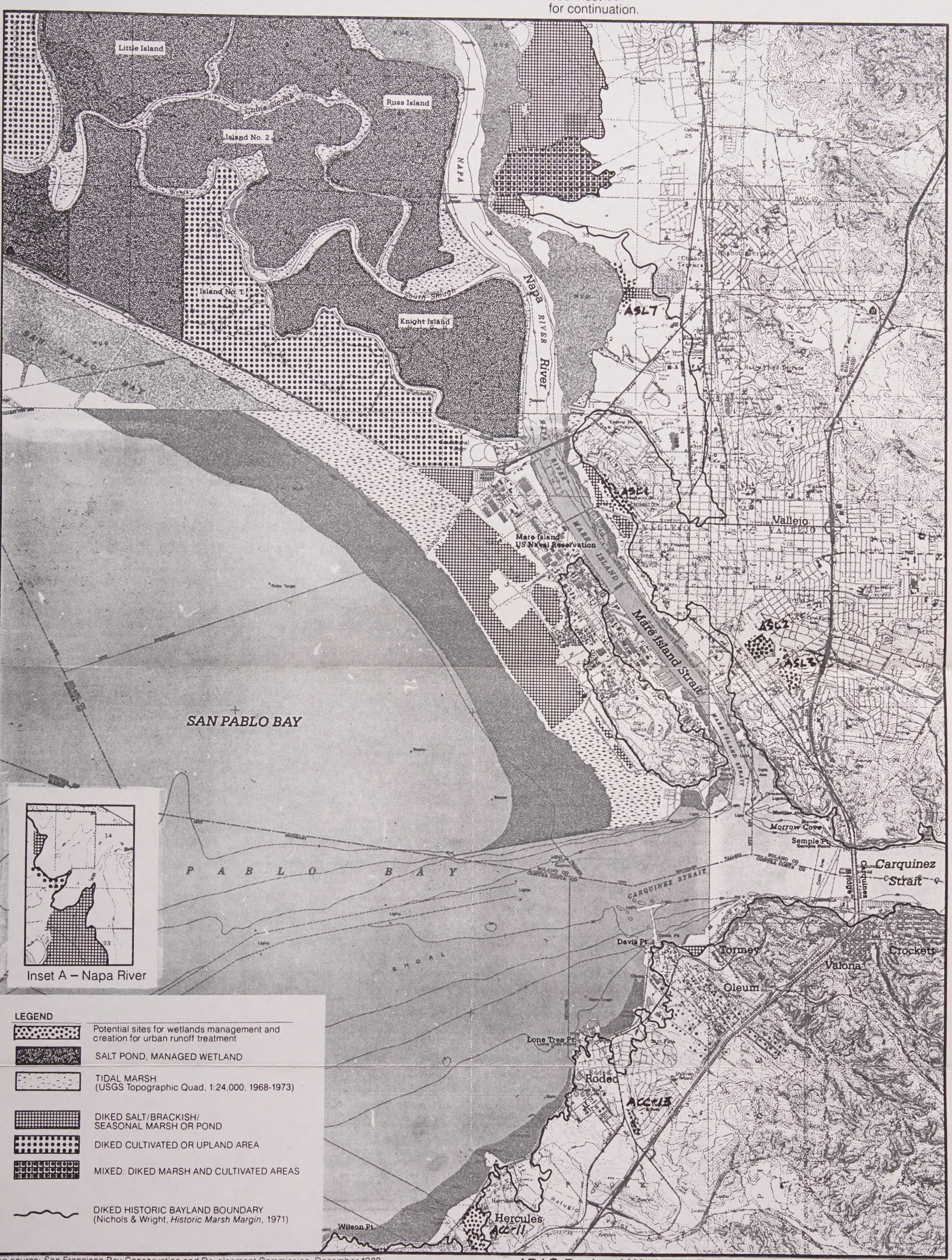
NORTH

MAP 12.
Napa Marshes

See Inset A
for continuation.



Map source: San Francisco Bay Conservation and Development Commission, December 1982

ABAG Regional Wetlands Program for Urban Runoff Treatment

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NORTH

MAP 13.

Eastern San Pablo Bay

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Map source: San Francisco Bay Conservation and Development Commission, December 1982

ABAG Regional Wetlands Program for Urban Runoff Treatment

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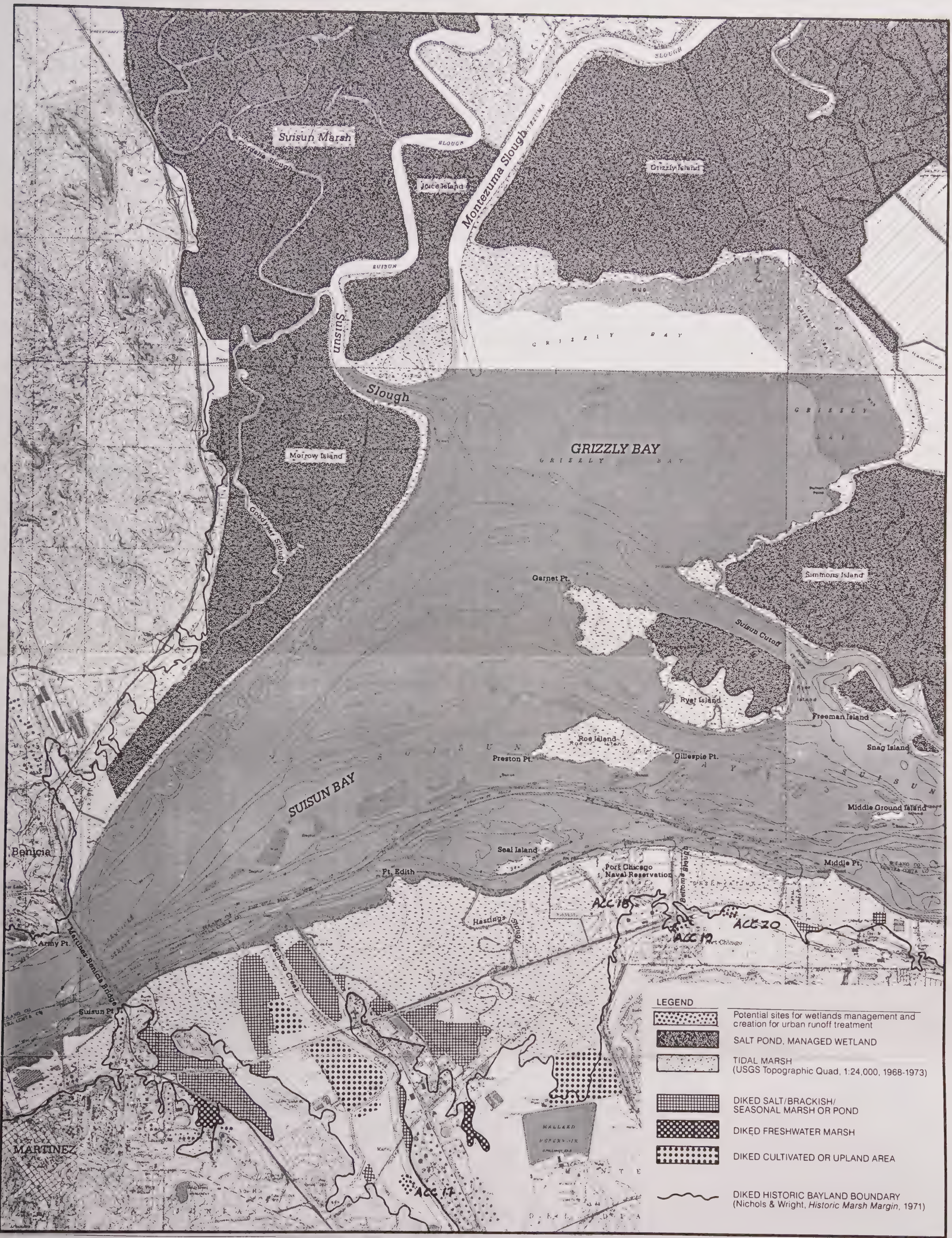
NORTH

MAP 14.

Carquinez Strait



Map source: San Francisco Bay Conservation and Development Commission, December 1982

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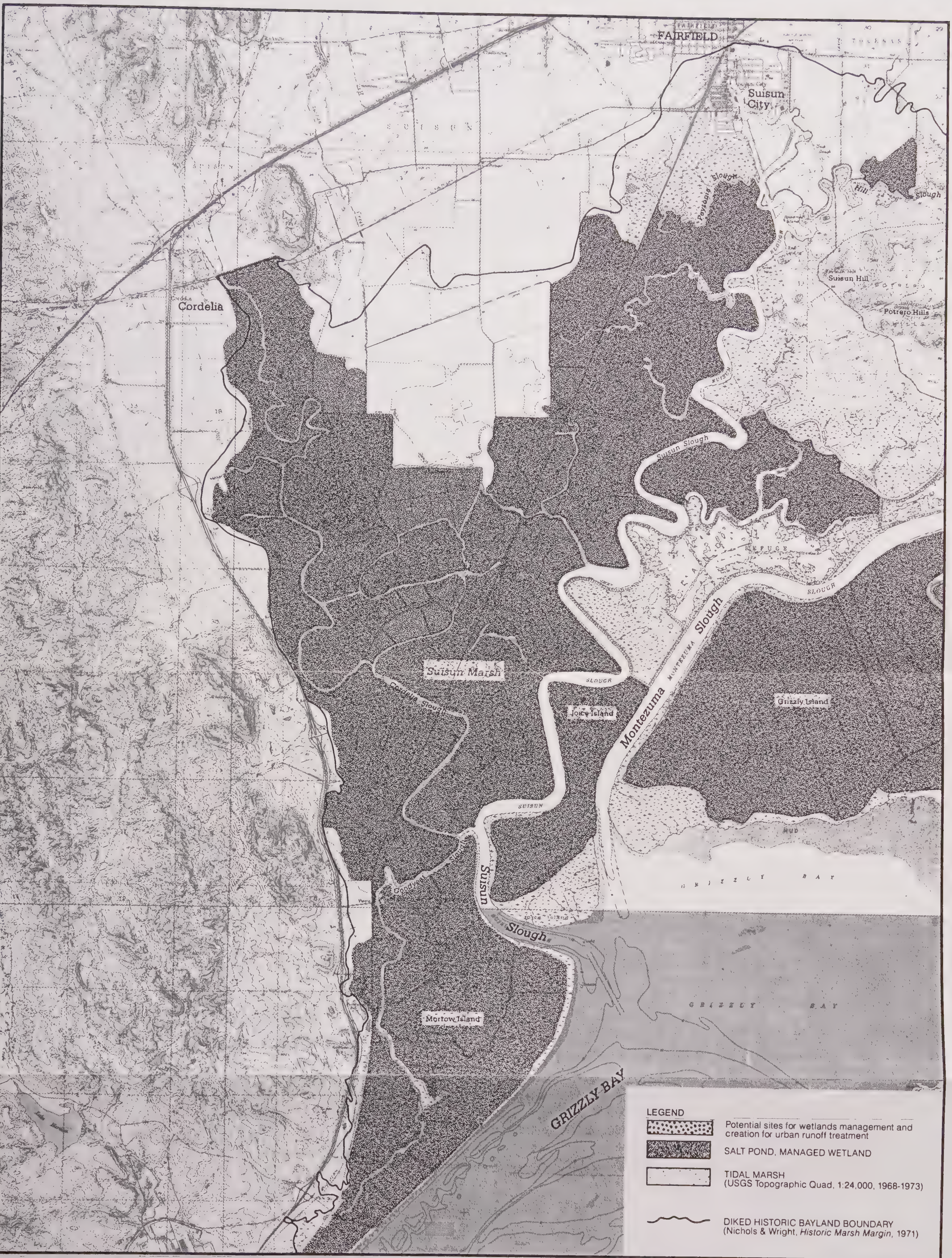
NORTH

ABAG Regional Wetlands Program for Urban Runoff Treatment

MAP 15.

Suisun Bay



Map source: San Francisco Bay Conservation and Development Commission, December 1982

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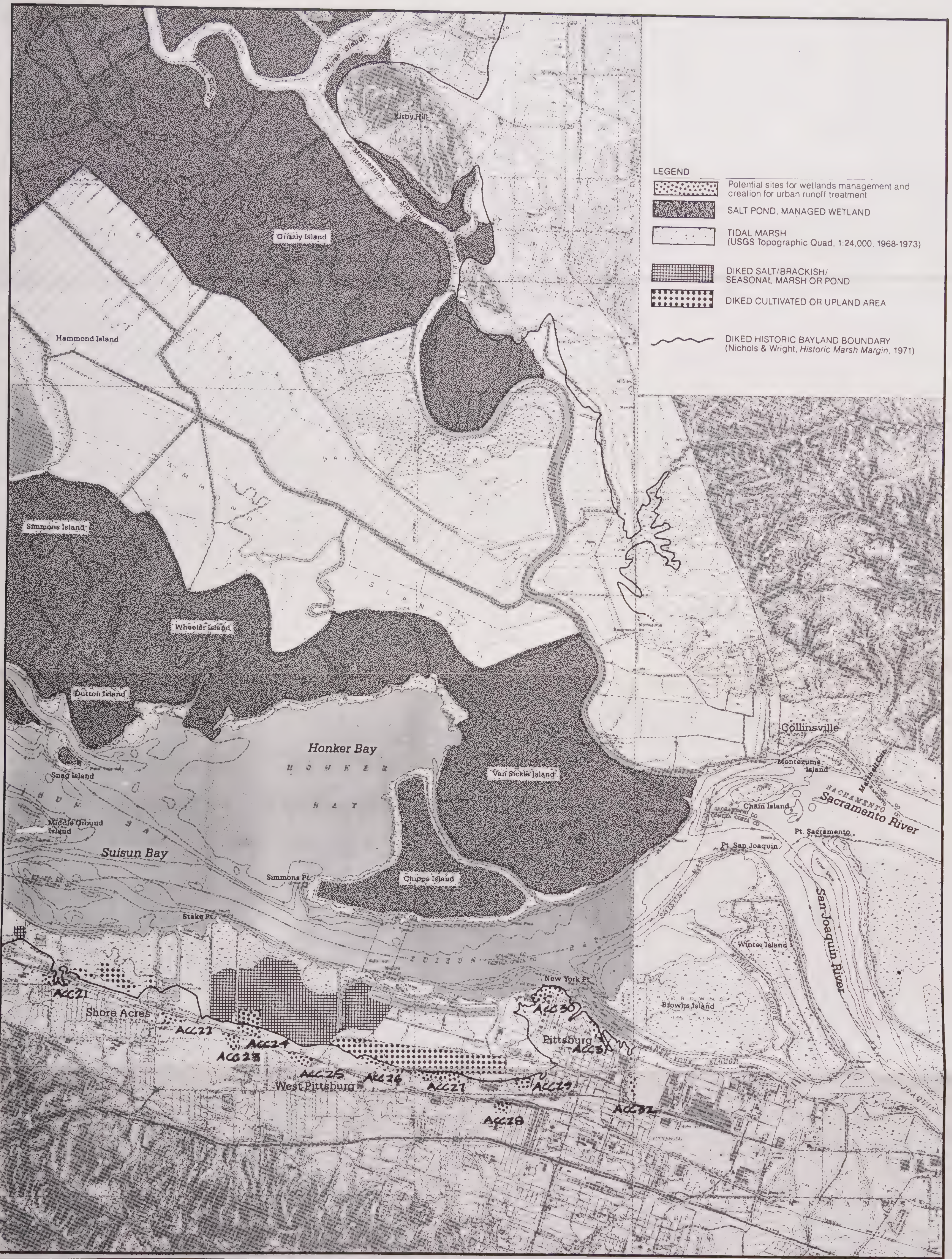
NORTH

ABAG Regional Wetlands Program for Urban Runoff Treatment

MAP 16.

Grizzly Bay



Map source: San Francisco Bay Conservation and Development Commission, December 1982

ABAG Regional Wetlands Program for Urban Runoff Treatment

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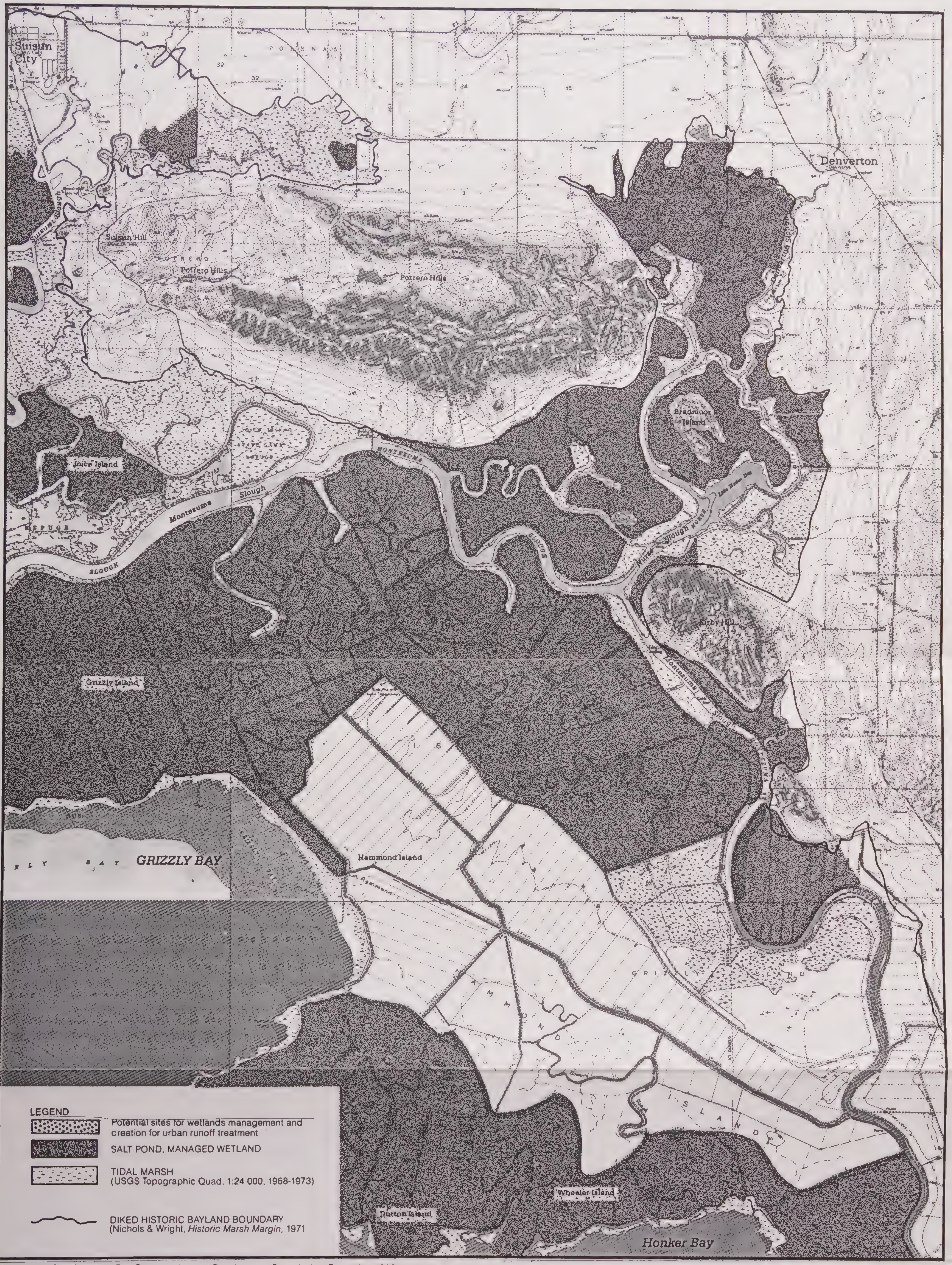
NORTH

MAP 17.

Honker Bay to Collinsville



Map source: San Francisco Bay Conservation and Development Commission, December 1982

ABAG Regional Wetlands Program for Urban Runoff Treatment

MAP 18.

Montezuma Slough

W.Q. Tech Memo No. 91
G. Silverman and E. Chan

REGIONAL WETLANDS PLAN FOR URBAN RUNOFF TREATMENT

FUNDING MECHANISMS AND POTENTIAL FUNDING SOURCES IN THE SAN FRANCISCO BAY AREA

Technical Memorandum No. 91
December 2, 1982

I. INTRODUCTION

The identification of potential financing mechanisms and the pursuit of possible funding sources are important steps in implementing projects to preserve, restore and create wetlands. Although wetlands have been broadly recognized as a valuable resource, knowledge of financing mechanisms is poor and there are few major programs for directly funding wetlands restoration or development. To the contrary, many wetlands are threatened due to the high value of alternative uses such as marinas or residential and business complexes. A number of potential funding sources and procurement mechanisms are identified in this paper applicable to wetlands projects in the San Francisco Bay Area.

A lack of financial support has often limited activities to implement wetland projects. Federal, state, regional and local governments, special districts, and a large number of special interest groups share, at least in part, a common commitment to enhance the wetland resource surrounding the San Francisco Bay. Two previous papers prepared as support documentation for the Regional Wetlands Plan for Urban Runoff Treatment contain descriptions of activities and conditions that could produce wetland projects, likely project participants and potential implementation mechanisms (1,2). Table 1 contains scenarios indicating how these groups could effectively interact to promote wetland activities. However, funding for these types of projects usually will require multiple sponsors, a mixture of funding sources, and in some cases a touch of creative financing. Mechanisms presented

TABLE 1. SCENARIOS FOR WETLANDS CREATION AND ENHANCEMENT

Activity that could produce wetlands	Participants	Rationale and/or Justification
Development of recreation areas: 1. wetlands park 2. pond/marsh sub-components in a park 3. urban trails/bikeways along riparian corridors 4. pond/marsh subcomponents in a golf course	o Cities and counties o Park districts o Recreation associations o Homeowners associations o Special interest groups	Multi-purpose planning--wetlands could provide urban runoff treatment, focal or highlight points for recreation areas
City/County General Plans-maintenance of special use or high development risk zones such as: 1. waterways and floodplains 2. unstable clay soils 3. airport hazard zones 4. wildland fire hazard and fire breaks 5. stream conservation 6. open space	o Cities and counties o Special districts (e.g., public works, flood control, fire department, park districts,	Wetlands creation can be compatible with some types of special use/risk zones due to: 1. similar habitat (streams, waterways and floodplains 2. complementary use - fire protection 3. coincidental use - open space areas, airports, etc. where wetlands would not interfere with normal uses.
Flood control, flood prevention and water supply facilities: 1. floodwater retention basins 2. flood channels (unlined) 3. impoundment basins 4. Channel dredging and disposal of dredge spoils	o Flood control districts o Water utility companies o Landowners o Special interest groups	Seasonal/permanent wetlands use can be compatible with: 1. low-flow or low-water conditions 2. short-term high water conditions 3. channel bank/bottom protection 4. lakes, ponds, unlined basins Flood control districts usually have long-term capital improvement programs where wetlands creation projects may be incorporated.

TABLE 1 (Continued)

Activity that could produce wetlands	Participants	Rationale and/or Justification
Abatement of urban runoff pollution in waterways storm sewers or water bodies	o Cities and counties o Regional Water Quality Control Board (RWQCB) o Large land development project owners/operators	RWQCB could require a local entity to reduce urban runoff pollution to Bay from their watershed. Local jurisdictions could choose wetlands treatment as a low-cost clean-up method.
Construction of a wetlands treatment system for combined municipal wastewater and stormwater.	o Local sanitary districts o Regional Water Quality Control Board	A sanitary district may choose wetlands treatment as an alternative low-cost facility.
Planning/implementation of erosion control plans with features such as: 1. sedimentation basins 2. retention/detention basins 3. temporary/permanent waterways, swales and dikes	o City/county public works department o Land development companies o Local landowners o Building/grading contractors	City/county grading ordinances often require erosion control plans for multi-unit development projects and public works projects. Semi-permanent wetlands could be incorporated into some types of erosion control measures that are compatible with final development.
Industrial/commercial/residential landscaping with features such as lakes, ponds, waterways, etc.	o Land developers o Landscaping contractors o Homeowners associations o Landowners	Water-oriented landscaping features, improve land values, provide focal points, aesthetic enhancement and also can receive and process urban runoff.
Commercial resource developments such as 1. duck clubs-hunting areas 2. pheasant farms 3. aquaculture-fisheries, algae, invertebrates, etc.	o Landowners o Recreation associations o Commercial groups	Some types of commercial resource developments require seasonal, partial or permanent flooding of land to create suitable growing habitat. Surface runoff can be used as a water source and wetlands are often compatible with these uses.

TABLE 1 (Continued)

Activity that could produce wetlands	Participants	Rationale and/or Justification
Shoreline development	o Bay Conservation and Development Commission o Army Corps of Engineers o Wildlife agencies o Cities and counties o Land developers	All shoreline activities require one or more permits. Activities affecting existing/historical wetlands often require wetlands restoration or enhancement to mitigate negative project impacts.
Improvement of shoreline environment for aesthetic value and recreational use	o Local jurisdictions o Park districts o Recreation associations o Special interest groups including conservation groups	Wetlands creation within shoreline zone could satisfy many purposes: 1. urban runoff treatment 2. environmental enhancement 3. wildlife habitat enrichment 4. recreational enjoyment
	o Local jurisdictions o Private developers	Local jurisdictions may encourage/require shoreline development projects to incorporate water-oriented facilities design.
Creation of wildlife refuge areas and nature preserves	o Wildlife agencies o Park districts o Cities and counties o Special interest groups o Conservation groups (e.g., Coastal Conservancy)	Waterfowl refuges and marsh preserves require wetlands incorporation. Surface runoff can be used to enhance or maintain wetlands
Creation of special educational facility at a wetlands with observation platforms, or special displays, laboratories or trained personnel	o Local jurisdictions o School districts o Special interest groups o Park districts o Natural history museums	Wetlands could be created or enhanced to provide a "living museum" or "outdoor classroom" for students
Research on wetlands processes or special aspects within wetlands	o Academic institutions o Research foundations and groups o Special interest groups	Wetlands can be created or modified to meet specific research objectives or to provide a wider range of study conditions.

in this paper should provide information useful in determining the availability of funds and, used in coordination with the scenarios, provide a good understanding of how to accomplish objectives for providing productive multipurpose wetlands.

II. FEDERAL FUNDING SOURCES

The U.S. Fish and Wildlife Service (FWS) has been active in protecting wetlands. Between 1935 and 1976, the FWS has acquired over 2.2 million acres of waterfowl habitat in the lower 48 states under provisions of the Migratory Bird Land Acquisition Program (3). This acquisition has been funded mainly through the sale of "duck stamps," and has not been an active program in the Bay Area.

The FWS acquires additional areas under the Land and Water Conservation Act to protect endangered species, to extend National Wildlife Refuges, and to protect important natural resource areas (3). The National Wildlife Refuge has been authorized to purchase 22,947 acres of land and open water in the South San Francisco Bay Area (4). However, these purchases generally preserve relatively large tracts of existing wetland habitat rather than restoring or developing new areas.

The Agricultural Stabilization and Conservation Service (ASCS) in the U.S. Department of Agriculture administers the Water Bank Program to pay landowners and farm operators to preserve the wetland quality of their lands. However, this program is mainly concentrated in the prairie pothole region of the upper Great Plains and has not been used in the Bay Area (3).

Federal funding is usually not available to finance projects such as the creation of small treatment marshes. However, some federal support can occasionally be obtained for local projects. For example, the U.S. Fish and Wildlife Service contributed $25,000 toward the planning and design of a new fresh and brackish water marsh system at the Hayward Regional Shoreline Marsh (5).

III. STATE FUNDING SOURCES

Some state funding is available for wetland acquisition and development projects. Section 26043 of the Public Resources Code lists 19 activities eligible for funding from the State Resources Account. Many of these activities deal directly with wetlands, most noteably (6):

> Wetland protection, preservation, restoration and enhancement projects in accordance with the Keene-Nejedly California Wetlands Preservation Act [Chapter 7 (commencing with Section 5810) of Division 5 of the Public Resources Code], or, in accordance with provisions governing the State Coastal Conservancy [Division 21 (commencing with Section 3100) of the Public Resources Code].

Other specified activities available for funding include land acquisition, and habitat restoration and preservation.

The Kapiloff Land Bank Act, passed in September 1982, provides for a special fund to finance state acquisition of wetlands (7). The State Lands Commission serves as Land Bank Trustee. The Commission acquires real property or interest in real property for public trust title settlements and for mitigation of projects adversely affecting existing or former wetlands. This fund is somewhat restrictive in providing only for the acquisition of land, with no provision for subsequent restoration or management. The Act does allow for the acquisition of "lands which have been or may be converted to wetlands," thus including areas outside the limits of historic marsh margin.

The California Coastal Conservancy has allocated approximately 2.2 million dollars for projects in the San Francisco Bay Area (8). While about $500,000 have already been spent, approximately 1.7 million dollars is potentially available for wetland preservation, restoration and development activities. The Conservancy will grant money to a large extent for projects that they deem most valuable to the region's wetland resource. Since few freshwater wetlands now exist around the Bay, the development of treatment wetlands would fulfill a Conservancy objective to create important habitats currently in short supply.

Funds for wetland development can be obtained directly through state legislative approval of bond issues. For example, $166,680 was designated from the State Parkland Bond Fund for the expansion of the Hayward Shoreline Marsh (5).

IV. LOCAL AND PRIVATE FUNDING SOURCES

The majority of the current activity to enhance and expand wetland habitat in the region focuses on lands within the historic marsh margin of San Francisco Bay identified by the U.S. Fish and Wildlife Service and California Department of Fish and Game (4). However, potential sites for urban runoff treatment wetlands are frequently located above this historic margin, outside the area of regulatory control by the Army Corps of Engineers and the Bay Conservation and Development Commission (1). Thus, local governments often must provide incentives and mitigation requirements to promote the creation of urban runoff treatment wetlands.

Local governments can finance wetland acquisition and development projects directly or through agencies such as park and flood control districts. However, local governments generally have very limited capability to finance wetland projects following the passage of Proposition 13 in 1978. Mechanisms are available for local government acquisition of lands at below market price, depending to a large extent on offering tax advantages for the gift or favorable sale of a wetland or potential wetland. Use of flood control basins, developed as seasonal wetlands without loss of flood control capacity, also offers

promise as a means to avoid land acquisition costs (2). However, even if land can be cheaply acquired, funds must be obtained to develop and manage the wetlands.

Private developers may be induced to develop wetlands as mitigation measures of proposed developments. In accordance with the California Environmental Quality Act, measures to mitigate potentially adverse environmental impacts must be included in the project Environmental Impact Report. The State Land Bank and the Trust for Public Lands offer means of facilitating the transfer of private land into publically owned or controlled wetlands as part of a mitigation settlement (1,2). Permit requirements imposed on developers may include funds for restoration and development, as well as land acquisition.

Acquisition and development of wetlands may also be financed through donations from private foundations. Several foundations in the Bay Area have policy objectives to support activities enhancing the environment. Although foundations historically have not played a major role in wetland activities, they may represent a largely untapped source of funding.

Financing of a wetland is unlikely to come exclusively from a single source. Coordination between several interested parties is usually required to successfully establish a wetlands. Case studies of the development of wetlands in Hayward and Fremont, described in ABAG Technical Memoranda No. 92 and 93 (5,9), give examples of the types of activities encountered in some successful wetland projects.

V. CONCLUSIONS

Means of financing projects to restore, acquire and develop wetlands are limited. A useful approach to successful project implementation is to try to minimize costs rather than maximize financial commitments. Land may be acquired at low cost through various incentive and mitigation schemes, or through the multiple purpose use of lands now dedicated exclusively to single activities such as flood control. Some system management may be available through the use of volunteer efforts from interest groups. However, some real financial commitment is unavoidable and remains the most significant obstacle to many wetland development projects. The various major programs for obtaining funds for wetland development are summarized in Table 2.

Wetlands designed to treat urban stormwater runoff offers the opportunity of creating valuable freshwater wetlands while providing some enhancement of water quality in the San Francisco Bay. Unfortunately, these benefits are usually not directly quantifiable. Treatment wetlands provide diverse benefits over an extended length of time. However, as is common with many environmental issues, costs must be borne by a much smaller group than those receiving benefits. This inequity between factions receiving costs with those obtaining benefits must be recognized and moderated to successfully implement a program to enhance and expand the Bay Area wetland resource.

TABLE 2. SUMMARY OF MAJOR POTENTIAL FUNDING SOURCES FOR WETLAND PROJECTS

Funding Source	Program/Authorization	Previous Activity and/or Funding Availability
U.S. Fish and Wildlife Service	Migratory Bird, Land Acquisition Program	2.2 million acres of habitat acquired between 1935 and 1976; none in Bay Area.
	Land and Water Conservation Act	Authorized 22,947-acre National Wildlife Refuge in South San Francisco Bay Area. 100,000 acres acquired nationally through 1977.
	Local assistance	$25,000 toward marsh expansion in Hayward
Agricultural Stabilization and Conservation Service	Water Bank	585,000 acres protected by 1979. None in Bay Area.
State Treasury Account	Environmental License Plate Fund	Funds vary yearly; dedicated to environmental uses.
State Lands Commission	Kapiloff Land Bank Act	Authorized September, 1982.
California Coastal Conservancy	Public Resources Code Section 31054 et. seq.	$2.2 million allocated for San Francisco Bay Area.
Local Governments	Implementation of city/county general plans	Land purchase and leasing, e.g. Coyote Hills in Fremont.
	Park Districts	Development of wetlands parks, e.g. Hayward Shoreline Marsh in Hayward.
	Flood Control Districts	Several, including flood basin at Coyote Hills in Fremont leased by Alameda County to develop wetlands.
Private developers	Mitigation or philanthropic	Several, including Muzzi Marsh, Marin County; Faber Tract, Palo Alto.
Special Interest Groups	Funding limited; provide services	Numerous
Foundations	Various	Largely untapped.

Although the problems inherent in obtaining funding for wetlands projects are substantial, funding often can be obtained and projects implemented. Two such projects, one in Hayward (5) and one in Fremont (9), have been described previously in support documentation prepared as part of ABAG's Regional Wetlands Plan for Urban Runoff Treatment. The means of obtaining financial support for these projects are summarized in Table 3. The implementation of these projects should provide encouragement to those who support and promote the enhancement of wetlands in the San Francisco Bay Area.

TABLE 3. FUNDING SOURCES FOR THE HAYWARD SHORELINE MARSH PHASE II EXPANSION (HSM) AND THE DEMONSTRATION URBAN STORMWATER TREATMENT MARSH AT COYOTE HILLS (DUST)

HAYWARD SHORELINE MARSH

Source	Dollar Amount (1982)	Purpose
U.S. Fish and Wildlife Service City of Hayward	5,000 2,500	Preparation of Concept Plan
U.S. Fish and Wildlife Service	20,000	Engineering Design and Preparation of Contract Documents
East Bay Regional Park District	20,000 (contributed staff time)	Prepare Environmental Documents and Permit Applications, Coordinate Engineering Designs and Contract Documents
City of Hayward East Bay Regional Park District	117,260 180,362	Land Acquisition
State Parkland Bond Fund State Coastal Conservancy	166,680 546,890	Construction
Total	1,058,692	

DEMONSTRATION URBAN STORMWATER TREATMENT MARSH

Source	Dollar Amount (1982)	Purpose
U.S. Environmental Protection Agency Association of Bay Area Governments East Bay Regional Park District	50,000 15,000 (contributed staff time) 10,000 (contributed staff time)	Planning, Design and Implementation
California Resources Account	200,000	Construction
East Bay Regional Park District Alameda County Flood Control District	-* -*	Change of Land Use
Total	260,000	

*Land costs were not included in total cost estimates, because no new lands were acquired. However, extrapolating from land acquisition costs at Hayward Marsh, ($297,662 for 200 acres); land acquisition costs for 50 acres at Coyote Hills would be approximately $74,000. These costs reflect zoning of these lands solely for open space uses.

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6. California Public Resources Code Section 26043.

7. California Public Resources Code Section 8600 et. seq.

8. Personal communication. John Zentner, California Coastal Commission, October 25, 1982.

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WQ. Tech. Memo. No. 92
Emy Chan

REGIONAL WETLANDS PLAN FOR URBAN RUNOFF TREATMENT

CASE STUDY OF MARSH PLANNING, DESIGN AND CREATION: HAYWARD SHORELINE MARSH - PHASE II

Technical Memorandum No. 92
December 2, 1982

I. INTRODUCTION

Wetlands creation and enhancement projects are recent developments in the San Francisco Bay Area that focus on transforming or renovating some of the residual coastal areas around the Bay into "high quality" or multiple-use wetland systems. While the operational goals of the various existing and proposed projects vary with the controlling entities, the common planning and design tools are artificial manipulation of the site (e.g. grading and flow control structures) and intensive site management. As wetland creation and restoration cannot compensate for the vast acreages of wetlands historically destroyed in the Bay Area, prudent stewardship of existing wetlands and the promotion of projects maximizing wetland uses and values become important.

The ABAG Regional Wetlands Plan centers on the creation of fresh and brackish water marshes and the use of wetlands to process surface runoff, particularly from urban areas. The overall result is an increase in valuable habitat and cultural resources, while at the same time effecting an improvement in local and Bay water quality through the natural cleansing mechanisms of wetlands (for a review of wetland pollutant treatment mechanisms and pollutant tolerances of wetlands, refer to "The Use of Wetlands for Water Pollution Control" Chan et.al., 1981). To date, only one wetland project has been created specifically to treat urban runoff pollutants: the 55-acre "Demonstration of Urban Stormwater Treatment" Marsh at Coyote Hills Regional Park in Fremont.

Wetlands creation and enhancement are evolving technologies that each new project contributes to the state-of-the-art in wetlands planning and design. Without rigid established guidelines for the development procedures, the most instructive information can often be obtained from the examination of similar successful projects. The case

study featured in this Technical Memorandum is Phase II of the Hayward Shoreline Marsh. The project highlights include an artificially-created and managed system that allows great flexibility in system monitoring and control, three diverse types of wetland habitats and treated municipal wastewater as the primary water source.

II. PROJECT INITIATION

The Hayward Shoreline Marsh Project forms a key part of the 1800-acre coastal restoration master plan of the Hayward Area Shoreline Protection Agency (HASPA). Portions of the project background and description have been excerpted from the "Hayward Regional Shoreline Marsh Expansion Project-Management Plan,"(EBRPD 1982).

Historically, the planning area was identified as a portion of a large salt and brackish marsh system along the east side of San Francisco Bay. This marsh was destroyed in the 19th Century by the construction of dikes to hold out tidal action and the creation of a series of commercial salt evaporation ponds. Salt production ceased in the 1940's, and much of the area, including the project site, has remained unused and in a degraded condition since that time.

About 400 acres of the total 1800-acre area was planned by HASPA to be restored to a diverse marsh system including salt, brackish and freshwater components. The East Bay Regional Park District (EBRPD), assisted by HASPA, has in recent years acquired site control (including the 400 acres designated for marsh restoration) by purchase of 495 acres and by long-term lease agreement (25 years) with other agencies. EBRPD is currently developing the area into the Hayward Regional Shoreline, as specified in the EBRPD Master Plan. When complete, the 400-acre Hayward Marsh (salt, brackish, and fresh) will be the largest wetland restoration and enhancement project on the West Coast to date (Figure 1).

The first phase of the marsh restoration and enhancement plan was completed in 1980 when the northern 200 acres of the 400-acre site were prepared and restored to tidal action by extensive grading and breaching of dikes. This area is rapidly becoming an established saltwater marsh. Funding for the development of this initial restoration was obtained from the California Department of Transportation (Caltrans), as a mitigation for impacts to wetlands during the construction of the new Dumbarton Bridge.

The second phase of the marsh restoration and enhancement plan, to which this case study is directed, involves restoration of 155 acres of land to fresh and brackish marshes, using existing and newly-created channels and dikes to form a five-basin marsh system. The project site is located immediately south of, and adjacent to, the Phase I salt marsh restoration site.

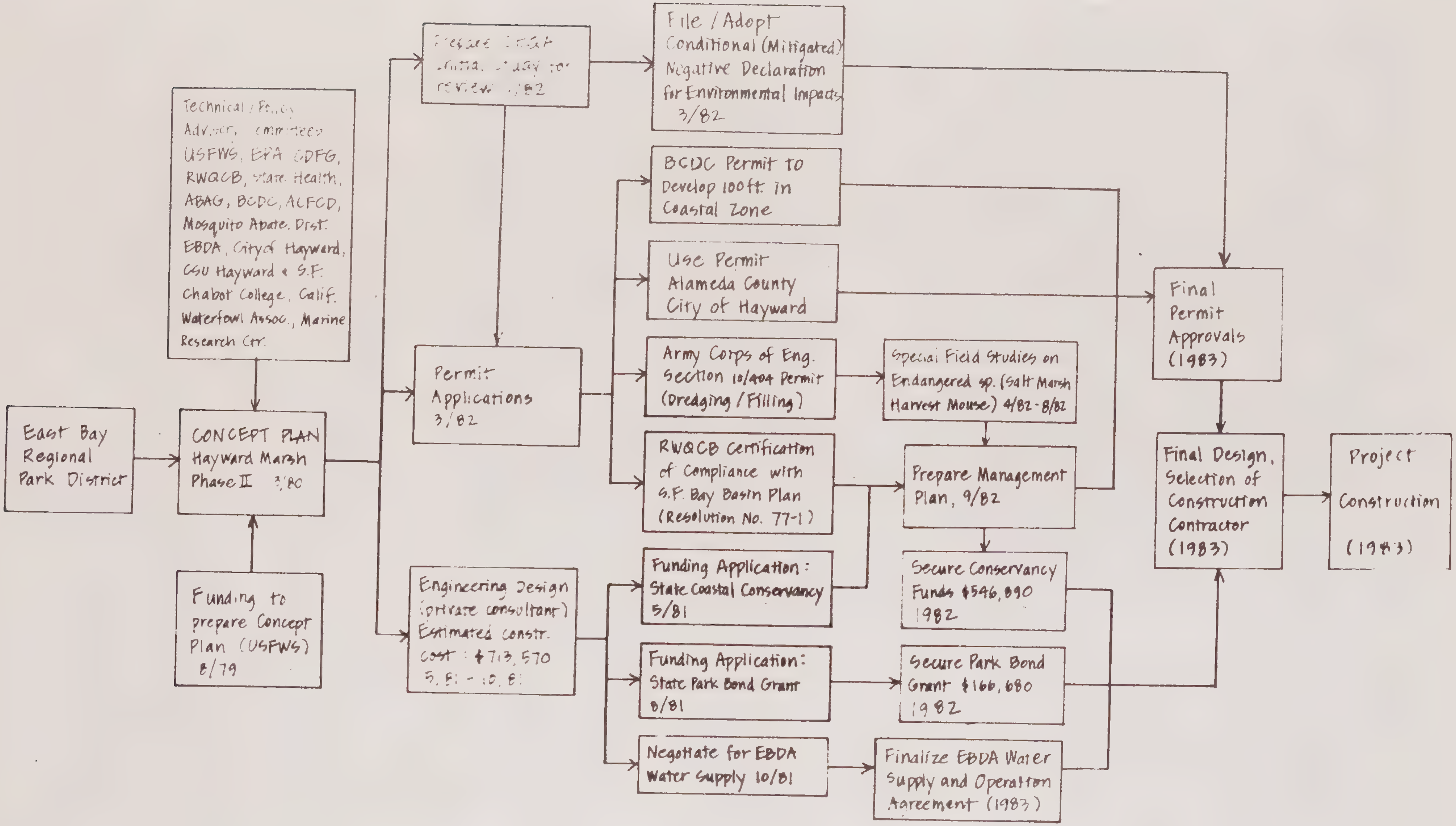

FIGURE 2. PROJECT ACTIVITY SEQUENCE: HAYWARD MARSH - PHASE II.

Districts and Flood Control Districts. The committee also includes representatives of EBRPD, the City of Hayward, the East Bay Dischargers Authority, and faculty from California State University Hayward, Chabot College, California State University San Francisco and representatives from the Marine Research Center and California Waterfowl Association.

Project Activity Sequence

The approximate time frame and sequence of project activities are shown in Figure 2. The planning and design stages for the Phase II Hayward Marsh covered approximately 18 months beginning in March 1980. The environmental review stage was conducted and completed in three months. The permit application stage is ongoing and it is anticipated that the final permit approvals will be obtained in early 1983, indicating a process and review time of close to one year. When all agreements have been made, grants obtained and permits secured, project construction is tentatively scheduled for spring and summer 1983.

III. PROJECT DESCRIPTION

Marsh System

The 155-acre fresh and brackish marsh system will consist of 5 basins with interconnecting channels. A separate 20-acre pickleweed marsh has been set aside as a preserve for the salt marsh harvest mouse (a rare and endangered species). Figure 3 shows the planned marsh configuration and includes locations of levees, channels, boardwalks, a regional shoreline trail and wildlife islands within the marsh basins. Table 1 summarizes the main project features, their size, water source, water detention times, vegetation type and anticipated wildlife use.

Reclaimed wastewater from the East Bay Dischargers Authority (EBDA) regional effluent disposal pipeline will be regulated by a valve structure as it enters Basin 1. Stormwater flows from the upstream 0.3 sq. mile watershed will enter the project's northwest channel below Basin 1 and flow directly out to the Bay without regulation. Tidal flows from the Bay into the central channel will be controlled by a large flood gate structure to allow manipulation of saltwater volumes with freshwater flows.

Basins 1, 2A and 2B will be the 85-acre freshwater marsh component of the wetland system. Basins 2A and 2B are identical in physical dimensions and features and can operate singularly or in parallel in order to facilitate comparison in research studies. These basins both discharge directly to the central channel.

Basins 3A and 3B form the 70-acre brackish water component. These basins are also roughly identical and can operate singularly or in parallel to facilitate research comparisons. A flood gate structure on the central inlet channel can be operated to control the amount of Bay water mixing with the freshwater effluent from the Basin 2 series, thus ensuring brackish water in the Basin 3 series. These basins both discharge to the northwest channel which empties into the Bay through a flap gate.

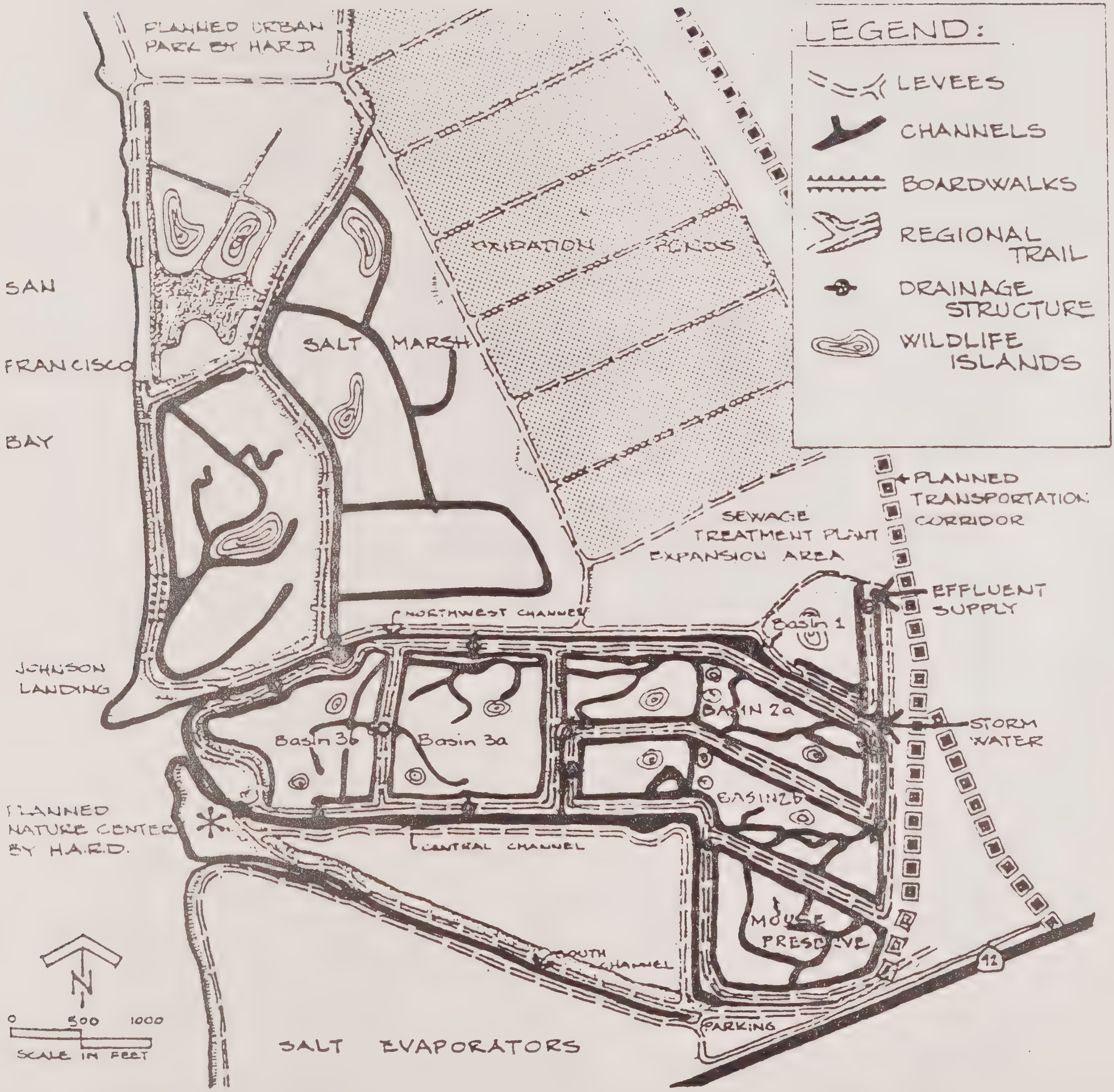

FIGURE 3. PROPOSED SITE DEVELOPMENT PLANS,
HAYWARD SHORELINE MARSH, PHASE II

TABLE 1. PROJECT SUMMARY: HAYWARD MARSH-PHASE II

Project Feature	Size (ac)	Water Source/Volume	Detention Time	Vegetation/ Habitat	Wildlife Use
Basin 1 transition pond (chlorination)	15	EBDA Reclaimed Water 6.5 - 18.2 mgd, 4.2 - 11.8 ft^3/s, Avg. 9.4 mgd	5-15 days Avg. 10 days (Including Basins 2A & 2B)	Open freshwater pond 6-ft deep, Submerged pond Vegetation: (*Potamogeton*, *Myriophyllum*, *Ruppia* etc.)	Waterfowl resting area
Basins 2A & 2B freshwater marshes	70	Basin 1	See Basin 1	Permanent shallow freshwater marsh 2-ft. deep, with 3 acres 6-ft. deep, Emergent vegetation: (*Typha*, *Scirpus*) planted alkali bulrush and watergrass.	Waterfowl feeding and nesting area
Basins 3A & 3B brackish water marshes	70	Basins 2A & 2B mixed with Bay water 15 ppt salinity minimum 3 mos./yr.	0-5 days (based on total detention with entire system of 10 days)	Permanent shallow brackish water marsh 1 to 2-ft deep, with 3 acres 6-ft. deep, Alkali bulrush (planted)	Wildlife Food, Shelter + nesting
Mouse Preserve	20	Bay water mixed with effluent from basins 2A & 2B	To be determined	Permanent shallow brackish water marsh infrequent inundation pickleweed (*Salicornia*)	Critical habitat for endangered salt marsh harvest mouse

The 20-acre pickleweed marsh mouse preserve will be infrequently inundated to sustain the desired habitat conditions. Bay water will enter the preserve through a pipe with a gate valve from the central channel.

All of the basins incorporate flow control structures for the inlets and outlets to allow maximum flexibility in manipulating hydraulic conditions, critical water levels for habitat and vector control, and drainage for maintenance procedures. In addition, flow control structures can allow water exchange between Basins 2A and 2B and similarly between Basins 3A and 3B.

Water Supply

Freshwater input to the marsh system will be obtained through an agreement with EBDA, a joint powers agency that collects wastewater from the East Bay communities between San Leandro and Union City. The main wastewater source for the marsh within the EBDA system will be secondary-treated effluent from the Alvarado Treatment Plant (Union Sanitary District). An auxiliary wastewater source will be secondary-treated effluent from the City of Hayward Treatment Plant. Effluent from the Alvarado Treatment Plant will require additional chlorination in the marsh Basin 1 component to meet water quality criteria of the Regional Water Quality Control Board (RWQCB).

Surface runoff from the immediate upstream drainage area-- Alameda County Flood Control District (ACFCD) line F, zone 4 -- will enter the northwest channel and exit out the western tide gate directly to the Bay. The watershed area is 183 acres from an urban portion of Hayward. For research and study purposes, surface runoff will not be mixed with the treated sewage effluent to reduce the number of study variables. Under normal operating conditions, surface runoff will bypass the basins. However, under storm flow and high tide conditions, water will be retained in the northwest channel and under high intensity storm conditions (e.g., peak flows up to 132 cfs during the 15-year storm) stormwater may be temporarily routed to Basin 3A or 3B.

Salt water input to the marsh system will be via a manually-controlled flood gate on the central channel. During high tide conditions, the amount of Bay water inflow can be arbitrarily controlled to suit the system needs: a mixture of fresh and salt water for Basins 3A and 3B, or undiluted Bay water for the pickleweed marsh mouse preserve.

Wetlands Operation and Management

The Hayward Marsh Management Plan delineated four areas for specific management and operation considerations: (1) water quality, (2) vector control, (3) botulism management, and (4) vegetation management. Table 2 summarizes the management criteria, techniques to achieve the desired results and the agency or legal authority requiring the measures.

TABLE 2. MANAGEMENT GUIDELINES: HAYWARD MARSH - PHASE II

Parameter	Management Criteria	Management Technique	Requirement/ Authority
Water Quality	1) Wastewater influent meets 2° treatment standards: 23 MPN/100 ml total coliform	Additional chlorination and/or contact time in Basin 1	RWQCB Waste Discharge Requirement (preliminary)
	2) 0.1 mg/l chlorine residual	5 to 15 day total retention time in Marsh system	"
	3) 0.025 mg/l un-dissociated ammonia	See (2) above	"
	4) 0.2 ml/l/hr settable solids prior to prior to final discharge	routine monitoring and action as necessary	"
	5) chlorophyll analysis prior to final discharge	Routine monitoring	"
Wastewater Use in Marshlands	1) Environmental benefits from discharge	Marsh creation	RWQCB Resolution No. 77-1
	2) Protection and enhancement of beneficial uses of receiving water	Improved water quality in system discharge	"
	3) Maximize benefits from water	See Management Plan	"
	4) Permanent commitment of land, operation and water processing	Management Plan	"
	5) Prepare Management plan and submit information for pilot investigation.	Management Plan	
Vector Control	Control mosquito populations (8 identified species at marsh site)	1) Biological control-mosquito fish and native fish species	RWQCB Resolution No. 77-1 and Alameda County Mosquito Abatement District
		2) Vegetation manipulation thinning and removal	"
		3) Water management-depth and circulation	"
		4) Monitoring of mosquito and predator populations	"

TABLE 2 Continued

Parameter	Management Criteria	Management Technique	Requirement Authority
Botulism Management	Reduce conditions that could lead to avian botulism: 1) poor circulation and standing shallow water	Design pond and channel areas to increase circulation and allow rapid slope/depth changes	RWQCB Resolution No. 77-1
	2) Detritus promoting C. botulinum growth and concentration in fly maggots	routine maintenance to remove medium for C. botulinum growth and fly maggot growth.	"
	3) Stagnant water conditions	continuous reclaimed water flow through system	"
	4) Infected waterfowl	Monitoring of waterfowl and coop. with Fish and Game.	"
Vegetation Management	Maximize environmental benefits and minimize nuisance problems	1) Establish variety of habitats as per management plan	RWQCB Resolution No. 77-1, and EBRPD management goals
		2) Maintain habitats through control of water levels and salinity	"
		3) Planting of species with high waterfowl food value	"
		4) Vegetation removal and thinning	"
		5) Routine inspection/maintenance	"
	Maintain habitat for salt marsh harvest mouse- endangered species	Maintain 20-acre pickleweed marsh preserve through infrequent bay water inundation and controlled access	Federal Endangered Species Act (USFWS)

IV. ENVIRONMENTAL REVIEW AND PERMIT PROCEDURE

The environmental review procedure began with the preparation and circulation for review of a CEQA Initial Study. The most significant impacts associated with the project were construction effects on the project site and changes in existing habitats. The construction effects could be mitigated by specific practices and it was judged that the new habitats created would be an improvement over the previous conditions. A small portion of the project site was found to support a population of the rare and endangered salt marsh harvest mouse. With the appropriate mitigation measure (site preservation) incorporated, the Board of Directors adopted a Conditional (Mitigated) Negative Declaration on Environmental Impacts. Copies of the Initial Study and Negative Declaration are included in the Hayward Marsh Management Plan.

Table 3 lists the permits associated with the Hayward Marsh project in the order of review and issuance. In principle, each permit or determination listed must be approved before the subsequent permit is granted. Thus the process begins with the CEQA determination and culminates with the Army Corps of Engineers Permit.

V. PROJECT COSTS

Total Project Costs

The total project cost for the Hayward Shoreline Marsh Phase II will be approximately $1,058,692 based on tentative 1981 construction cost estimates. A breakdown of the project costs into the planning and design, land acquisition and construction subcomponents is given below:

Planning and design (1980 - 82)	$ 47,500
Land acquisition (1978)	297,622
Estimated construction cost (1981)	713,570
Total	$1,058,692

The land for the marsh restoration project was purchased in 1978. Based on a comparison of the 1968 purchase price by the previous owner and the 1978 purchase prices by EBRPD and the City of Hayward, the land values have remained the same and no increase in land value was assumed between 1978 and the present (Personal communication, Martin Storm, City of Hayward, 10/28/82).

A summary of the estimated construction cost is presented in Table 4. The preliminary cost estimate was made in October 1981, with the anticipation that construction would run from June through November 1982. Project delays were encountered when special field studies for an endangered mouse species and the preparation of a management plan were required. If all project approvals are met, construction could begin in Spring 1983, however construction costs may change from the initial

TABLE 3 ENVIRONMENTAL REVIEW AND PERMIT REQUIREMENTS FOR HAYWARD MARSH RESTORATION-PHASE II

Agency/Permit	Permit Requirements	Additional Information
State Determination of Environmental Significance	CEQA Initial Study, Adopted Negative Declaration (Conditional) on Environmental Impacts	
Alameda County and City of Hayward Use Permit	Approved CEQA Initial Study and Negative Declaration Concept Plan Conformance with General Plan	
Regional Water Quality Control Board - Certification of Complance with S.F. Bay Basin Plan	Submit Management Plan meeting policy criteria of Resolution No. 77-1 "Policy and Guidelines on the Use of Wastewater to create, restore, maintain and or enhance marshlands	Supplemental Info. on water quality
Bay Conservation and Development Commission Permit for 100-ft coastal development	Concept plan, Approved CEQA Initial Study and Negative Declaration	
Army Corps of Engineers Section 10/404 permit (dredging and Filling)	Concept plan, Approved CEQA Initial Study and Negative Declaration	Field Studies and Management plan to satisfy Federal Endangered Species Act

TABLE 4. HAYWARD SHORELINE MARSH - PHASE II CONSTRUCTION COST SUMMARY

Item		Cost $
Mobilization		25,000
Basin 1 (15 acres)		124,900
Earthwork (19,900 yd^3)	$71,400*	
Drainage	53,500	
Basin 2 (60 acres)		281,000
Earthwork (64,200 yd^3)	268,000*	
Drainage	12,900	
Basin 3 (90 acres)		117,200
Earthwork (20,600 yd^3)	85,400*	
Drainage	31,800	
Outer levee protection		26,350
Miscellaneous earthwork and drainage structures		24,300
Planting		25,000
Signs, gates and fences		25,000
Contingency (10%)		64,870
Total Construction Cost		713,570

Source: East Bay Regional Park District, Preliminary Cost Estimate for Hayward Marsh Restoration 10-13-81.

* Based on grading cost estimates of $3/yd^3$ for surface scraping and $4.50/yd^3$ channel dredging.

estimate in 1981. In addition, current negotiations with EBDA over the cost of the reclaimed water connection and related activities may raise the construction cost 10 to 15%.

Project Sponsors and Funding

The major project sponsors during the planning and design phase were the U.S. Fish and Wildlife Service, the EBRPD and the City of Hayward. Table 5 presents the division of project components among these sponsors.

The restoration project is part of the Hayward Shoreline Marsh as planned by HASPA. The original land purchase for Phases I and II were conducted in 1978 where EBRPD spent $730,000 for 495 acres and the City of Hayward spent $556,000 for the upland 148 acres. EBRPD funds were derived from 1974 and 1976 Bond Act grants. As no subdivision of land cost between the Phase I and II projects has been made, the land value was computed on a per acre basis. Hayward's portion was funded by 1974 and 1975 Bond Act grants and the split for Phase II was computed at $117,260 for 77.7 acres with the Phase II project. The City of Hayward leases the land to EBRPD for a nominal annual fee.

Project construction will be funded by two separate entities. For the construction of the Phase I Hayward Marsh, EBRPD obtained a grant from the State Parkland Bond Fund. The remainder not used during Phase I construction ($166,680) was designated for Phase II construction costs. The Parkland Bond Grant covered less than one-fourth of the estimated Phase II construction costs and EBRPD applied for and received a grant from the State Coastal Conservancy for the balance of the costs.

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TABLE 5. HAYWARD SHORELINE MARSH-PHASE II PROJECT SPONSOR AND SPONSOR AMOUNTS

Project Component	Sponsor	Sponsor Amount $	Total $
Planning and Design			
Preparation of Concept Plan (including aerial photos)	U.S. Fish and Wildlife (Sacramento)	5,000	47,500
	City of Hayward	2,500	
Engineering design and preparation of contract	U.S. Fish and Wildlife Service (Sacramento)	20,000	
Prepare environmental documents and permit applications, coordinate engineering design and contract documents	East Bay Regional Park District	20,000*	
Land Acquisition			297,622
Basin 1, portions of Basins 2A,2B, mouse preserve (77.7 acres)	City of Hayward	117,260	
Portions of Basins 2A, 2B, Basins 3A & 3B, Basin 4 (123 acres)	East Bay Regional Park District	180,362	
Construction Costs			713,570
	State Parkland Bond Fund	166,680	
	State Coastal Conservancy	546,890	
Project Total			1,058,692

* Contributed staff time

W/Q Tech Memo No. 93
G. Silverman

REGIONAL WETLANDS PLAN FOR URBAN RUNOFF TREATMENT

CASE STUDY OF MARSH PLANNING, DESIGN AND CREATION: COYOTE HILLS DEMONSTRATION URBAN STORMWATER TREATMENT (DUST) MARSH

Technical Memorandum No. 93
December 2, 1982

I. INTRODUCTION

The creation and restoration of wetlands receiving and treating urban stormwater runoff provides valuable habitat while protecting the water quality of the San Francisco Bay. As part of the Association of Bay Area Governments (ABAG) Regional Wetlands Program, evaluations have been made regarding the mechanisms and resources needed to implement wetland projects. This Technical Memorandum provides documentation of the process and major considerations used in creating the only wetland in the Bay Area specifically constructed to treat urban stormwater pollution--the Coyote Hills Demonstration Urban Stormwater Treatment (DUST) marsh in Fremont. Detailed reviews of the project design and prevailing water quality conditions are available in ABAG's Water Quality DUST Project Report No. 1 (1) and No. 2 (2).

This is the second case study contained in the ABAG Regional Wetland Program, the other describing Phase II of the Hayward Shoreline Marsh project (3). These two case studies were prepared to demonstrate successful wetland projects. A major environmental objective for the San Francisco Bay Area identified by various levels of government, interest groups and individuals, is wetlands preservation, restoration and creation. The largest obstacles to wetland development are often the lack of financial support (4) and the lack of coordination between groups supporting varied interests (5). Through the evaluation of these past projects, an understanding can be gained regarding means of overcoming these obstacles and implementing plans that promote wetlands.

PROJECT INITIATION

Background

Creation of the Coyote Hills Urban Stormwater Treatment Marsh is a joint project of ABAG and the East Bay Regional Park District (EBRPD). The marsh will be managed as part of the regional park at Coyote Hills (Figure 1) and, if funding permits, used extensively as a research facility. The marsh is located in Fremont (Figure 2) and receives a runoff from both urban and non-urban drainages.

The concept of using a marsh system to treat urban runoff in the Bay Area was developed as part of the San Francisco Bay Areawide (208) Water Quality Management Program conducted by ABAG. Pollution from surface runoff has been shown to be a significant problem in the Bay Area (6). Policy 8 of the Water Quality Management Plan for the San Francisco Bay Area calls for the establishment of "a program of surface runoff controls that emphasize low cost measures to reduce pollutant loads from this source" (7). A number of methods for controlling non-point source pollution have been evaluated in the ABAG Surface Runoff Program. The results of this program indicate that the use of marsh systems to treat runoff offers great potential for a practical means of controlling stormwater pollution into the San Francisco Bay (8).

The development of wetlands specifically to treat urban stormwater previously has not been done in the Bay Area, and little is mentioned in the literature concerning development in other parts of the world. However, wetlands are receiving increasing attention as effective waste water treatment systems (9). The efficiency of urban stormwater treatment wetlands can be extrapolated from design principles and pollutant removal mechanisms common to wastewater treatment systems.

The Coyote Hills Demonstration Urban Stormwater Treatment Marsh was designed for use as a research facility to test the capability of various wetland designs and loading rates in removing pollutants found in urban runoff. Information obtained through site monitoring will be used to evaluate the practicality of implementing a comprehensive plan for the Bay Area reducing non-point source pollution through the use of wetlands.

Project Objectives

The primary goal of this project is to determine the applicability of wetland creation for stormwater treatment in the San Francisco Bay Area. This project is also expected to increase and enhance the wetland habitat at Coyote Hills Regional Park, and offer related benefits associated with the creation of a wetlands used as a regional park. Specific objectives of this project are:

- o To demonstrate urban stormwater runoff treatment through a wetlands;
- o To prove the cost-effectiveness of this treatment method;

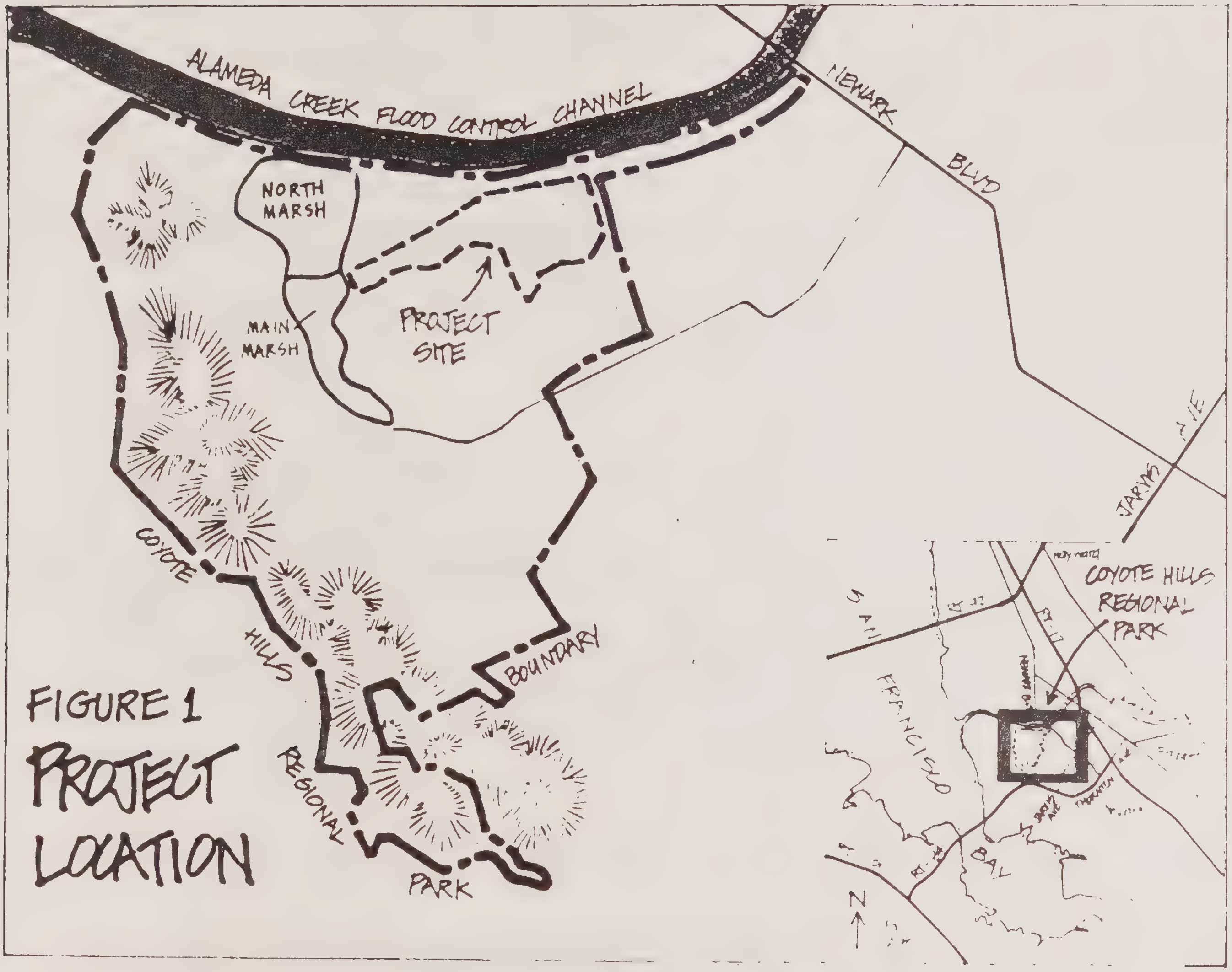

FIGURE 1
PROJECT LOCATION

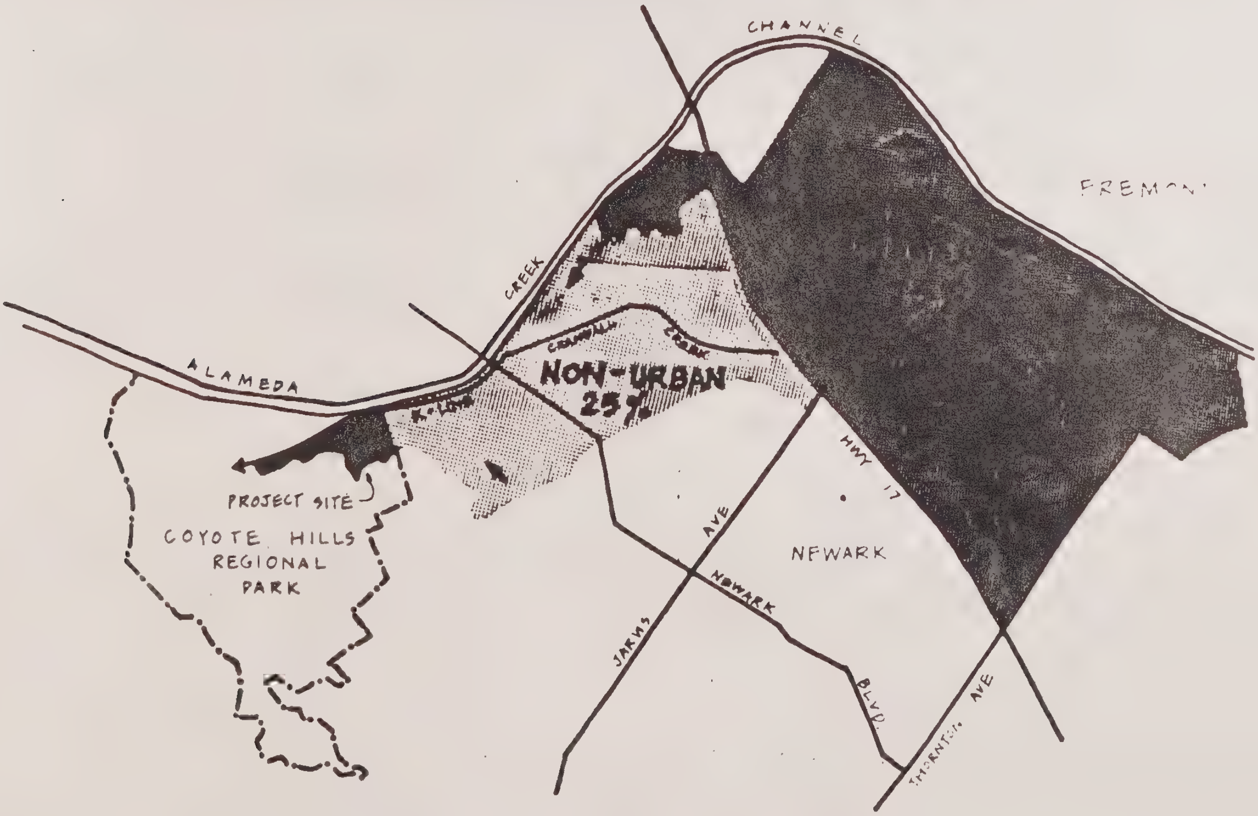

FIGURE 2. DRAINAGE AREA TRIBUTARY TO PROJECT SITE

- o To demonstrate the design and construction of a new wetland;
- o To compare the treatment effectiveness of various wetland types;
- o To create fresh/brackish water marshes and increase the local habitat diversity; and
- o To study marsh succession and fate of urban runoff pollutants.

Project Participants

Creation of the Demonstration Urban Stormwater Treatment Marsh is a joint project of ABAG and EBRPD. The concept of constructing an experimental runoff treatment wetland was formulated by ABAG as part of the San Francisco Bay Areawide (208) Water Quality Management Program. Design and implementation of the project was done as a cooperative effort between ABAG and EBRPD. The marsh will be constructed partially on land owned by EBRPD and partially on lands leased to EBRPD from the Alameda County Flood Control District (ACFCD). Research regarding the performance of the wetland system is a priority interest of ABAG, although funding is very limited. Facility management is the responsibility of EPRPD.

Assistance was obtained during planning and design of the DUST marsh from representatives of the following agencies:

- o U.S. Army Corps of Engineers (COE)
- o U.S. Fish and Wildlife Service (FWS)
- o National Marine Fishery Service (NMFS)
- o California Department of Fish and Game (DFG)
- o San Francisco Regional Water Quality Control Board (RWQCB)
- o Alameda County Mosquito Abatement District (ACMAD)
- o Alameda County Flood Control District (ACFCD)
- o Alameda County Water District (ACWD)

The Association of Bay Area Governments' Water Quality Citizen Advisory Committee (CAC) and Technical Advisory Committee (TAC) also participated in project planning and review.

Project Activity Sequence

The sequence of project activities are shown in Figure 3. The project will take approximately two years from conception to construction. Subsequent monitoring of the facility should be conducted for several years to adequately determine the capability and potential value of runoff treatment marshes.

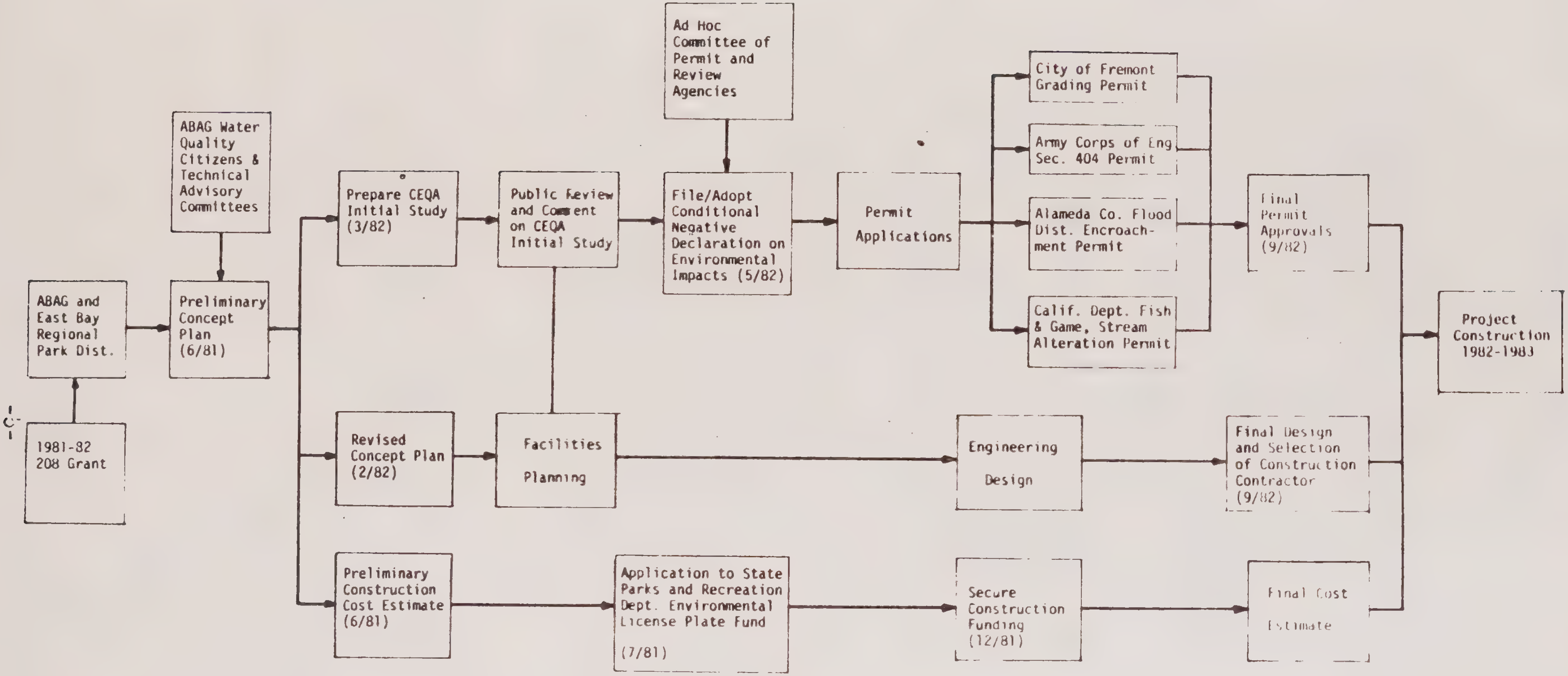

FIGURE 1. PROJECT ACTIVITY SEQUENCE, COYOTE HILLS DEMONSTRATION OF URBAN STORMWATER TREATMENT MARSH

PROJECT DESCRIPTION

Marsh System

Surface runoff from Crandall Creek (designated "K" line by the Alameda County Flood Control District) will be diverted into the northeast corner of the wetland (Figure 4). The diversion weir will be overtopped and washed out at an elevation of +5 feet, a situation that should occur during peak flow from the 5 year (6 hour) storm. The DUST marsh is designed to handle peak flow from at least the 10 year storm, so the marsh will not cause a loss of flood control capacity in the area (1). Water will be divided between parallel flow systems, A and B, offering different wetland conditions. The systems discharge into a common system, C, offering a third wetland condition. Initial plans for a fourth system, D, paralleling systems A and B, have been postponed due to lack of funds.

System A consists of a large pond with side slopes of 4:1 and contains two islands. The pond has a surface area of approximately 6 acres and a maximum storage volume of about 30 acre-feet. The pond and islands are long and narrow to maximize edge for water contact with rooted vegetation. It is anticipated that most of the shoreline and islands will become heavily vegetated with cattails. Cattail marshes have been shown to have a potential for removal of significant quantities of several pollutants, including phosphorus (10,11) nitrogen, (10,12,13) BOD (13) and some heavy metals (14).

System B consists of an initial small pond, an overland flow area, and a linear second pond divided by submerged berms constructed perpendicular to the direction of flow. Water will enter the system at a small pond which will act as a distribution system to spread water over the overland flow system. Pickleweed will probably become established at the overland flow area. While pollutant removal efficiency cannot be forecasted, the pickleweed should be effective in providing a large area of substrate for physical entrapment and adsorption of pollutants. Water will move across the overland flow and enter a long pond shaped to maximize contact with rooted plants. The submerged berms should become thickly vegetated with cattails, and provide an obstacle to flow that may effectively "comb" remaining solids from the water.

System C is designed to provide an area of shallow, meandering channels, maximizing contact with various types of wetland vegetation. The extent of channel construction will depend on the availability of funds. The system will discharge through submerged pipes into "North Marsh" at low flows when water surface elevation is below +3 feet. During periods of moderate flows, with water surface elevation greater than +3 feet, water will also discharge over a +3 feet weir into "Main Marsh". During extreme conditions, with water surface elevation above +4 feet, water will overtop a second weir and flow into "North Marsh".

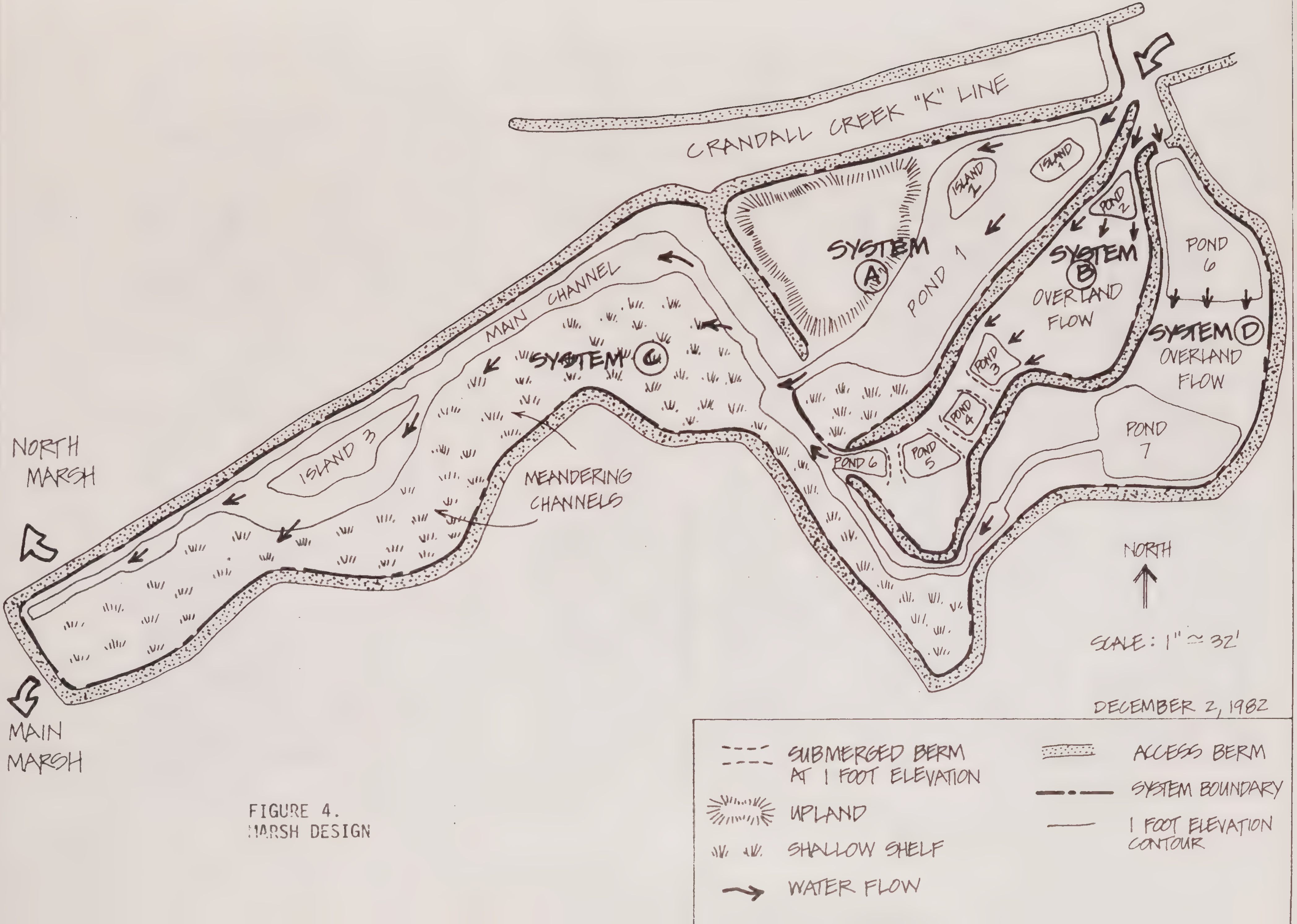

FIGURE 4.
MARSH DESIGN

Marsh Expansion

At some later date when additional funds are obtained, System D will be developed to treat the agricultural runoff from the Patterson Ranch just upstream from the site. Until System D is developed, this agricultural runoff will be diverted into System B to prevent upstream flooding. Additional funding will also allow greater channelization of System C.

Water Supply

The main supply of water to the site will be from the diversion of Crandall Creek at the northeast corner of the project, draining approximately 4.6 square miles. Approximately 75% of the drainage area is urban and composed mainly of residential areas with some commercial development. The remaining 25% is predominantly agricultural with open space areas for utility easements and flood control facilities (Figure 2). Residential development is anticipated for much of the undeveloped and agricultural land. A relatively small, but unquantified, amount of agricultural runoff enters the project from a neighboring farm.

Since the wetland will receive only freshwater inputs, it should eventually become a freshwater wetlands. However, monitoring of shallow wells at the site indicate that considerable amounts of salt are present in the soil (2). Thus, the wetland may be somewhat brackish until the system is adequately flushed.

Operations and Management

The marsh will be managed by the East Bay Regional Park District and used as a research facility. The system was designed to require a minimal amount of active maintenance. A summary of the management plan is presented in Table 1. A detailed description of design considerations to create a low maintenance system is presented in ABAG Technical Memorandum 94 (1).

ENVIRONMENTAL REVIEW AND PERMIT PROCEDURE

The permits obtained for the DUST marsh are identified in Table 2. Three major concerns were expressed during project planning and review. The Mosquito Abatement District expressed a concern that the salt marsh mosquito (*Aedes squamiger*) might become a nuisance. This concern was mitigated through the planned introduction of mosquito fish (*Gambusia affinis*) and the creation of deep ponds as sustaining fish habitat during the dry season. Vehicle access will also be maintained on the levees and overland flow areas to allow other treatment if mosquito fish do not prove an adequate control. The Alameda County Flood Control District expressed a concern that no flood control capacity be lost through project development. The project was designed to result in greater storage and flow capacity than had previously existed. The California Department of Fish and Game were concerned that the project would result in the loss of valuable transitional habitat. The area was mapped with respect to both existing conditions and conditions

TABLE 1. COYOTE HILLS DUST MARSH MANAGEMENT PLAN

Management Requirement	Management Technique
Control mosquito populations. Target species is Aedes squamiger which breeds in brackish to salt water in late fall through spring and is dormant summer through fall.	1. Biological control-maintain mosquito fish (Gambusia) populations; during the summer, each system must maintain wet area for fish reservoir. 2. Vegetative manipulation-thinning and removal as necessary. 3. Drainage ditches as needed.
Control vegetation to maximize environmental benefits and minimize nuisance problems.	1. Allow establishment of wetland vegetation along ponds and channels. 2. Vegetative manipulation-thinning and removal as necessary in wetlands. 3. Mowing or heading of overland flow areas annually to reduce matting if necessary.
Maintain flow-through circulation and minimize water quality nuisance problems.	1. Vegetative manipulation-thinning and removal as necessary in channels and ponds. 2. Occasional channel dredging if necessary (e.g., every 20 years).
Maintain flood control capacity of ACFCD "J-Pond" and integrity of "K-line" water channel.	1. Removal of excessive vegetative growth where it reduces flood retention capacity or flow. 2. Maintenance of diversion weir to project on "K-line" channel.

TABLE 2. ENVIRONMENTAL REVIEW AND PERMIT REQUIREMENT FOR COYOTE HILLS DEMONSTRATION URBAN STORMWATER TREATMENT MARSH CREATION

Agency/Permit	Permit Requirement
State Determination of Environmental Significance	CEQA initial study, adopted negative declaration (conditional) on environmental impacts.
Army Corps of Engineers Section 404 Permit	Concept plan. Approved CEQA initial study and negative declaration. No net loss of wetlands.
Department of Fish and Game Stream Alteration Permit	Minimize disturbance and environmental degradation. Protect water quality. Limited construction period to protect fish and wildlife.
City of Fremont Grading Permit	Exempt due to lack of fill or export to the site.
Alameda County Flood Control and Water Conservation District Encroachment Permit	No reduction in storage capacity or obstruction to flow.

anticipated after project completion. The extent of various habitats were tabulated for each condition in order to evaluate the effect upon habitat. Transitional and openwater areas were found to be greatly increased due to the project, with some loss of uplands. These changes in habitat type were acceptable to DFG as advantageous changes to local wildlife populations.

PROJECT COSTS

Total Project Costs

The development and creation of the "DUST" marsh cost approximately $260,000 in 1982 dollars. No land costs were considered because part of the site is currently owned by the EBRPD and the remainder is being leased at a nominal cost from the ACFCD. A summary of project costs is presented in Table 3.

Project Sponsers and Funding

The project design was financed jointly by a Section 208 grant from the U.S. Environmental Protection Agency matched by funds provided by ABAG and EBRPD. Construction funds were provided by an Environmental License Plate Fund grant administered by the California Department of Parks and Recreation. Funds have not yet been obtained for monitoring and use of the system as a research facility. A summary of project funding is shown on Table 4.

TABLE 3. SUMMARY OF COSTS FOR DEVELOPING THE DEMONSTRATION URBAN STORMWATER TREATMENT MARSH AT COYOTE HILLS

Item	Dollar Amount (1982) Current Project	Dollar Amount (1982) Project Expansion
Planning, Design and Implementation	$ 70,000	Included in current project
Construction		
Earthwork		
Inlet Structures	14,000	
Systems A and B	142,000	
System C		$ 42,900
Partial dredging of System C and contingencies	29,900	
System D		104,400
Drainage Structures	14,100	
Miscellaneous Facilities and Services		10,000
Land Costs	No new land acquisition. Market value of land.*	Included in current project
Total	$270,000	$157,300

*Land costs were not included in total cost estimates, because no new lands were acquired. However, extrapolating from land acquisition costs at Hayward Marsh ($297,662 for 200 acres), land acquisition costs for 50 acres at Coyote Hills would be $74,000. These costs reflect zoning of these lands solely for open space uses.

TABLE 4. SUMMARY OF FUNDING SOURCES FOR THE DEMONSTRATION STORMWATER TREATMENT MARSH AT COYOTE HILLS

Source	Dollar Amount (1982)	Purpose
Environmental License Plate Fund	10,000	
EPA	$ 42,500	Planning Design and Implementation
ABAG	75,000 (contributed staff time)	
EBRPD	10,000 (contributed staff time)	
Environmental License Plate Fund	$200,000	Construction
EBRPD	--	Use of existing parkland
ACFCD	--	Use of flood basin

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SAN FRANCISCO BAY AREA

REGIONAL WETLANDS PLAN

FOR URBAN RUNOFF TREATMENT

VOLUME I
PLAN AND
AMENDMENTS TO THE
ENVIRONMENTAL MANAGEMENT PLAN

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SAN FRANCISCO BAY AREA
REGIONAL WETLANDS PROGRAM
FOR URBAN RUNOFF TREATMENT

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I. INTRODUCTION

This document presents the results of ABAG's 1981-82 water quality planning program. These study results and recommended additions to the San Francisco Bay Area Environmental Management Plan were issued in draft form in December 1982 for public review and to solicit suggestions for improvements. The ABAG Executive Board voted in April 1983 to include Policy 13 in the Environmental Management Plan based on the results of this program.

BACKGROUND

Pollution from surface runoff is a priority problem in the Bay Area as well throughout the State of California. Surface runoff seasonally contributes 9 percent of the total suspended solids loading to all waters of the San Francisco Bay system and up to 100 percent of the loading to inland waters. A substantial part of the heavy metal load to the Bay - up to 63 percent - is primarily associated with this source. The estimated total metals loading is 1.7 million kilograms/year (expressed as chronic toxicity equivalent of chromium) and enters the system in the forms of As, Cd, Cr, Cu, Hg, Ni, Pb and Zn. Estimated concentrations of heavy metals are an order of magnitude higher in surface runoff from urban areas than non-urban areas or Delta outflow. Urban areas are a significant pollutant source of other important urban runoff constituents which include BOD, pesticides, organics and hydrocarbons (oil and grease), as shown in Table 1. In sufficient concentrations, any of these can have damaging effects on aquatic animals and plants in streams, lakes, estuaries and sloughs as well as causing damage to the San Francisco Bay ecosystem.

In June 1980 the State Water Resources Control Board included urban runoff as a priority water quality problem. The approved Water Quality Management Plan for the San Francisco Bay Area, adopted by ABAG in June 1978, contains Policy 8 which reads: "Establish a program of surface runoff controls that emphasize low cost measures to reduce pollutant load from this source."

The ABAG Surface Runoff Program has evaluated and recommended a number of pre-treatment methods at the pollutant sources - particularly street surfaces and construction areas. Local communities often have difficulty implementing measures such as street sweeping and catch basin cleaning because the equipment and the operation schedule is inefficient and funds for public works measures have been cut back as local budgets have decreased. Additionally, it has become apparent from investigations of the public works practices, that more intensive measures requiring large and expensive efforts may reduce runoff pollution by only a modest degree and cannot substantially benefit the receiving waters. This is due to two principal factors: (1) public works services, such as street sweeping or sewer cleaning are intermittent and cannot provide continuous control of pollutants; and 2) public works services are usually applied to discrete portions of the

urban land area although runoff pollutants originate from the total area. Thus, a different approach for urban runoff pollutants may be order.

TABLE 1.

RELATIVE CONTRIBUTION OF URBAN RUNOFF TO SAN FRANCISCO BAY

Constituent	Fraction of All Bay Inputs (%)[a]	Fraction of Local Inputs to Bay (%)[b]	Fraction of Bay Inputs (%)[b] (Oct. - April)
BOD_5	12	19	32
TSS	1	5	9
Total N	3	5	9
Total P	1	1	2
Heavy Metals	21	43	60
Oil & Grease	c	28	44

a. With Delta contribution
b. Without Delta contribution
c. Unknown

Reference: Russell et.al., 1981

DEVELOPMENT OF WETLANDS PROGRAM TO TREAT URBAN RUNOFF

An alternative to pre-treatment at the pollutant source, which often must cover a large area and can be labor and equipment intensive, is treatment of the surface runoff stream before it enters receiving waters. This can supplement public works practices and provide a workable alternative to communities that have difficulty controlling pollutants at their source.

Use of a marsh system to treat urban runoff combines the features of a conventional wastewater treatment lagoon with a natural biological purification system. As the final step in processing surface runoff prior to discharge to the Bay, wetland systems are very effective at removing gross pollutants (BOD, suspended solids and some nutrients) and accumulating trace pollutants (such as heavy metals and organics).

In 1978-80, ABAG conducted and prepared for EPA a State-of-the-Art review of pollutant control through hydraulic and vegetative practices titled: "The Use of Wetlands for Water Pollution Control," (Chan et.al., 1981). At the same time, a field study was performed at the Palo Alto baylands on treatment of stormwater runoff through a marsh/flood basin. In the Palo Alto study, the wetlands were found to significantly remove suspended sediments and associated pollutants and accumulate trace heavy metals. The system had received surface runoff for many years and no chronic adverse effects related to urban runoff were noted.

The results of the State-of-the-Art review of wetlands treatment and the Palo Alto Flood Basin study indicated a potential for urban runoff treatment through wetlands in other Bay Area communities. The natural treatment capabilities of wetlands systems could become a rationale for obtaining public/private funding for wetlands creation, enhancement and management and would not detract from the multiple purpose uses of wetlands such as wildlife habitat, recreation and open space.

The translation of this concept into action was inaugarated with the 1981-82 ABAG Water Quality Planning Program. The major product is the preparation of the Regional Wetlands Plan for Urban Stormwater Treatment. The plan reviews:

- o the use of wetlands in relation to water quality protection;
- o wetland values in the Bay Area;
- o regulations and authority over wetlands development;
- o local policies and opportunities for wetlands creation and management;
- o mechanisms for wetlands creation and enhancement; and
- o guidelines for selecting potential wetland sites.

The Regional Wetlands Plan forms the basis for a proposed new policy and actions on wetlands to be adopted into the Water Quality Management Plan portion of the Environmental Management Plan. Technical memoranda providing supplementary information on various aspects of the plan are included in Volume II of the Plan.

An associated activity was the planning, design and implementation of a demonstration marsh creation project for urban runoff treatment at Coyote Hills Regional Park in Fremont. The major objectives were to create the first artificial marsh project specifically designed to treat urban runoff and to prove to local jurisdictions that this was a practical and economic solution to problems with nonpoint source pollution in the Bay Area.

THE ENVIRONMENTAL MANAGEMENT PLAN

The Environmental Management Plan (EMP) for the San Francisco Bay Area was adopted by the General Assembly of the Association of Bay Area Governments (ABAG) in June 1978. The EMP was prepared with assistance from the San Francisco Bay Regional Water Quality Control Board (RWQCB), the Bay Area Air Quality Management District, the Metropolitan Transportation Commission and the region's nine counties. Preparation of the initial plan was guided by a 46-member Environmental Management Task Force (EMTF), a policy advisory body to the ABAG Regional Planning Committee (RPC) and Executive Board. The plan presented a series of actions that showed how the region could solve air, water and solid waste problems in the Bay Area, and meet key Federal and State standards.

The water quality portions of the EMP are collectively referred to as the Water Quality Management Plan (WQMP) for the San Francisco Bay Area. They were prepared to meet the requirements of the Federal Water Pollution Control Act Amendments of 1972 and 1977.

The WQMP addresses water quality problems in the Bay Area in four major areas of concern. These are:

1) actions dealing with receiving waters and health of the ecosystem;
2) actions directed at municipal and industrial point sources of wastewater discharge;
3) surface runoff pollution control activities; and
4) miscellaneous pollution sources such as septic tanks, vessel wastes and chemical spills.

The WQMP identifies specific policies and actions which would greatly alleviate, if not eliminate, water pollutants and pollution-related problems in the Bay Area.

II. AMENDMENTS FOR THE ENVIRONMENTAL MANAGEMENT PLAN

The policy and actions that follow have been added to the adopted WQMP.

Policy 13: Wetlands are important for water quality protection among other ecological benefits, and should be preserved and enhanced; new wetlands should be created for urban runoff control as appropriate.

Action 13.1 Evaluate and disseminate information on wetlands in relation to water quality protection.

Action 13.2 Evaluate potential wetland treatment facilities and benefits during water quality protection facility planning.

Action 13.3 Implement wetland treatment systems for polluted waters, where appropriate and economically justified.

Action 13.4 Consider wetlands enhancement or creation projects as alternate mitigation measures offsetting negative environmental impacts of development projects.

Action 13.5 Local governments should incorporate wetland systems into their general plans as appropriate.

Action 13.6 Wetlands or specific parts of wetlands constructed for water pollution control should be considered as artificial devices discharging to waters-of-the-state.

A description of the new Water Quality Management Plan actions and their associated environmental impacts are summarized in Table 2 which has been amended into the ABAG Environmental Management Plan, Chapter III - Water Quality Management, Section F - Plan Recommendations, Table 5 - Water Quality Management Plan Recommendations. This plan does not alter the authority or responsibility of any agency; implementation of this plan by local agencies is voluntary.

This plan applies to any wetlands, existing of future, natural or artificial, that provides or could provide water quality improvement. For purposes of this plan, wetlands must have one or more of the following three attributes:

(1) The substrate is predominantly undrained hydric soil;

(2) The substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year; and

(3) The land supports predominantly hydrophytes.

This is a very broad definition and includes systems with largely differing characteristics including water treatment capabilities.

TABLE 2. POLICY AND ACTIONS FOR ADDITION TO THE ENVIRONMENTAL MANAGEMENT PLAN

[illegible]	GENERAL DESCRIPTION	RESPONSIBLE AGENCY OR AGENCIES	SCHEDULE FOR ACTION	LEGAL AUTHORITY	TOTAL COST [illegible] OF RECOMMENDED ACTION	PORTION OF TOTAL COST [illegible] ATTRIBUTABLE TO THIS PLAN	FINANCING MECHANISM	MEASURES TO ENSURE IMPLEMENTATION
[illegible]	WETLANDS ARE IMPORTANT FOR WATER QUALITY PROTECTION AMONG OTHER ECOLOGICAL BENEFITS, AND SHOULD BE PRESERVED AND ENHANCED; NEW WETLANDS SHOULD BE CREATED FOR URBAN RUNOFF CONTROL AS APPROPRIATE.							
[illegible]	Current information on wetlands projects and research related to water quality should be compiled, evaluated and made available to interested persons or groups.	ABAG, colleges, universities and special interest groups concerned with wetlands activities.	Ongoing	Not applicable	Undetermined	Undetermined	Federal and State grants and/or local and private funds	Voluntary

ENVIRONMENTAL IMPACTS	INSTITUTIONAL/FINANCIAL IMPACTS	ECONOMIC IMPACTS	SOCIAL IMPACTS
Air Quality o No impacts. Water Quality o Would improve water quality indirectly--provides data to make informed decisions. Physical Resources o Would benefit physical resources indirectly as water quality is improved, e.g. the aquatic community, flora, fauna and recreation. Energy o No impacts. Amenities o Would affect amenities indirectly; highly dependent on type of activities where wetland information is used.	Financial o Costs would be met by participants and persons or groups seeking wetlands information. Institutional o May result in higher level of cooperation among agencies, educational institutions and special interest groups concerned with wetlands activities. o May improve credibility and accuracy of research and study results.	Production of Goods and Services o No impacts. Income and Investment o No impacts. Consumer Expenditures o Minor costs to secure information from compiling source.	Housing Supply o No impacts. Physical Mobility o No impacts. Health and Safety o Might uncover health and safety problems as result of research. o Could affect decisions on water quality that affect public health. Sense of Community o No impacts. Urban Patterns o No impacts.

TABLE 2. Continued

RECOMMENDATIONS	GENERAL DESCRIPTION	RESPONSIBLE AGENCY (OR AGENCIES)	SCHEDULE FOR ACTION	LEGAL AUTHORITY	TOTAL COST/YEAR OF RECOMMENDED ACTION	PORTION OF TOTAL COST/YR. DIRECTLY ATTRIBUTABLE TO THIS PLAN	FINANCING MECHANISM	MEASURES TO ENSURE IMPLEMENTATION
Action 13.2. Evaluate potential wetland treatment facilities and benefits during water quality protection facility planning.	Municipal wastewater and urban stormwater facilities plans should include wetlands as one alternative treatment system.	Cities, counties and special districts involved with water quality protection.	As facilities become needed.	FWPCA Sec.208 (b)(2)(A)	Undetermined	-0-	Federal and State grants and/or local funds.	Voluntary

ENVIRONMENTAL IMPACTS	INSTITUTIONAL/FINANCIAL IMPACTS	ECONOMIC IMPACTS	SOCIAL IMPACTS
<u>Air Quality</u> o Temporary dust problems during construction of wetlands and conveyance facilities. o Nearby recreational areas may be subject to odors from marsh operations. o Localized air pollutant emissions may occur with auto access to facilities. <u>Water Quality</u> o Wetland treatment systems would reduce suspended solids, oxygen-demanding substances, some nutrients and heavy metals in surface runoff and advanced wastewater treatment. <u>Physical Resources</u> o Water quality improvements enhance habitat and benefit fish and wildlife resources. o Wastewater and surface runoff treatment facilities in wetlands can provide new recreational opportunities. o Wetland treatment facilities design can enhance recreation uses/natural resources in selected areas as tradeoffs for development project impacts. o May reduce existing wildlife habitats and recreational uses at proposed project sites. o May create potential for food chain contamination in the constructed wetlands, while creating an increased potential for protecting food chains in the Bay. <u>Energy</u> o Incremental consumption of gas, electricity and diesel fuel during wetlands construction. o Wetland water supply and operation may require electricity/fuel for pumping/conveyance. <u>Amenities</u> o Improved visual amenities through construction of new or enhanced wetlands systems and open space preservation.	<u>Financial</u> Direct Costs of Implementation (Public and/or private): o Land acquisition costs are site-specific o Design and construction costs are project specific. Example costs: -20-acre wetland system receiving 1.5 mgd secondary wastewater: total cost = $94,000 (Mt. View Sanitary District, Martinez, 1980) -55-acre urban runoff treatment wetland: total cost = $450,000 (Coyote Hills Park - East Bay Regional Park District, 1981) -140-acre wetland research system receiving 9.4 mgd secondary wastewater: total cost estimated at $760,000 (Hayward Shoreline Marsh Phase II - East Bay Regional Park District, 1981). o Operation and maintenance costs are project specific. Example costs: -20-acre wastewater wetland system: $1200/yr. + 6 person-months (Mt. View Sanitary District, Martinez, 1980). Fiscal Effects on Local Governments: o Specific fiscal impacts on implementing entity depend on choice of financing mechanisms and extent of private involvement. o Bonds, special assessment fees, and user charges would increase local government revenues. o Property tax revenue may decrease if wetland area rezoned from development categories. o Potential $ savings in multipurpose facilities: development costs may be negligible for recreational facilities. o Indirect fiscal impacts would result from costs to provide public services to new facilities. <u>Institutional</u> o Would fulfill and integrate recreation, open space and other elements of local general plans. o Proper facilities design and operation would minimize odor problems, and protect existing wildlife habitats or compensate for any reductions.	<u>Production of Goods and Services</u> o Employment - temporary and permanent job creation would depend on individual project construction and operation. <u>Income and Investment</u> o Increased wages and salaries may result from jobs created. o Facilities construction and operation may compete for local agency funds. o Wetland treatment facilities costs should be planned to provide benefits ($/pollutants removed) exceeding costs of other treatment methods. <u>Consumer Expenditures</u> o Operation and maintenance costs of multi-purpose facilities may be paid for by user charges.	<u>Housing Supply</u> o May indirectly benefit housing rehabilitation programs where new recreation opportunities and open space are provided. <u>Physical Mobility</u> o Localized, short-term disruptions in mobility may result during construction. o New recreational facilities associated with projects can be designed for handicapped persons access. <u>Health and Safety</u> o Water quality improvements can reduce health risks in project areas. o Indirect health benefits accrue from improvement of wildlife sport populations through cleaner wastewater discharges and surface runoff. <u>Sense of Community</u> o Improved visual amenities of open space can contribute to stronger sense of community. o New recreation opportunities in local areas promote sense of community. <u>Urban Patterns</u> o May change development patterns. <u>Equity</u> o User charges and property tax increases would impact low and moderate income households differently than high income households. o Some types of recreation opportunities provide benefits only to localized areas.

TABLE 2. Continued

RECOMMENDATIONS	GENERAL DESCRIPTION	RESPONSIBLE AGENCY (OR AGENCIES)	SCHEDULE FOR ACTION	LEGAL AUTHORITY	TOTAL COST/YEAR OF RECOMMENDED ACTION	PORTION OF TOTAL COST/YR. DIRECTLY ATTRIBUTABLE TO THIS PLAN	FINANCING MECHANISM	MEASURES TO ENSURE IMPLEMENTATION
Action 13.3. Implement wetland treatment systems for polluted waters where appropriate and economically justified.	Wetland systems to be implemented where treatment benefit exceeds the incremental cost and is compatible with local recreation or open space plans.	Cities, counties and special districts involved with water quality protection.	As facilities become needed.	Not applicable.	Undetermined	-0-	Local funds.	Voluntary
Action 13.4. Consider wetlands enhancement or creation projects as alternative mitigation measures offsetting negative environmental impacts of development projects.	Where development projects may impact existing wetlands with degraded or marginal habitat value, marsh restoration or enhancement should be considered. Where projects result in loss of open space lands, marshes may be constructed as replacements.	Project lead agencies, permitting and funding agencies as appropriate.	During CEQA review of project or when permits are issued.	CEQA (CRC Title 14, Sec. 14085(h))	-0-	-0-	Not applicable.	Voluntary.
Action 13.5. Local governments should incorporate wetlands systems into their General Plans, where appropriate.	Wetlands creation or enhancement projects can fulfill the objectives of one or more General Plan elements and also be used as a vehicle to integrate various Plan elements.	Cities, counties and special districts involved with land use and water quality planning	Annually or when General Plan is periodically updated.		Undetermined	Undetermined	Local funds.	Voluntary.

ENVIRONMENTAL IMPACTS	INSTITUTIONAL/FINANCIAL IMPACTS	ECONOMIC IMPACTS	SOCIAL IMPACTS
Impacts same as noted for Action 13.2.	Impacts same as noted for Action 13.2.	Impacts same as noted for Action 13.2.	Impacts same as noted for Action 13.2.
Impacts same as noted for Action 13.2.	Impacts same as noted for Action 13.2.	Impacts same as noted for Action 13.2.	Impacts same as noted for Action 13.2.
<u>Air Quality</u> o No impacts. <u>Water Quality</u> o Would improve water quality indirectly by promoting wetland projects. <u>Physical Resources</u> o Would benefit physical resources indirectly as water quality is improved, e.g. the aquatic community, flora and fauna. <u>Energy</u> o No impacts. <u>Amenities</u> o Would affect amenities indirectly dependent on type and extent of wetlands projects.	<u>Financial</u> Direct Public Costs of Implémentation: o No impacts. Fiscal Effects on Local Governments: o No impacts. <u>Institutional</u> o Local governments can integrate high priority wetlands habitat needs with long-range planning. o May require additional staff resources to reevaluate General Plan elements and implement recommendations.	<u>Production of Goods and Services</u> o No impacts. <u>Income and Investment</u> o No impacts. <u>Consumer Expenditures</u> o No impacts.	<u>Housing Supply</u> o May indirectly affect new housing construction where overall densities are reduced to incorporate wetland system. <u>Physical Mobility</u> o No impacts. <u>Health and Safety</u> o No impacts. <u>Sense of Community</u> o Would indirectly improve sense of community through promotion of open space and new recreation opportunities. <u>Urban Patterns</u> o No impacts. <u>Equity</u> o No impacts.

TABLE 2. Continued

RECOMMENDATIONS	GENERAL DESCRIPTION	RESPONSIBLE AGENCY (OR AGENCIES)	SCHEDULE FOR ACTION	LEGAL AUTHORITY	TOTAL COST/YEAR OF RECOMMENDED ACTION	PORTION OF TOTAL COST/YR. DIRECTLY ATTRIBUTABLE TO THIS PLAN	FINANCING MECHANISM	MEASURES TO ENSURE IMPLEMENTATION
Action 13.6. Wetlands or specific parts of wetlands constructed for water pollution control should be considered as artificial devices discharging to waters-of-the-state.	This action would not apply to natural wetlands or wetlands constructed as mitigation for loss of other wetlands. This action applies to wetlands receiving waters that are not waters-of-the-state. For wetlands treating municipal wastewaters, public access would be restricted commensurate with the degree of health risk involved unless additional treatment is provided to permit multiple use objectives, e.g. canoeing and treatment. Monitoring may be necessary.	Regional Water Quality Control Board	To take effect immediately.		No increase in costs to state budget. Possible decrease in cost of wetlands.	100%.	State budget for RWQCB activities.	Certification of this Plan by SWRCB.

ENVIRONMENTAL IMPACTS	INSTITUTIONAL/FINANCIAL IMPACTS	ECONOMIC IMPACTS	SOCIAL IMPACTS
<u>Air Quality</u> o No impacts. <u>Water Quality</u> o Would improve water quality as treatment wetlands discharges must meet specified discharge criteria. <u>Physical Resources</u> o Would benefit physical rewources indirectly as water quality is improved, e.g. aquatic community, flora and fauna. <u>Energy</u> o No impacts. <u>Amenities</u> o No impacts.	<u>Financial</u> Direct Costs of Implementation (Public or Private): o Decreased project costs due to less stringent initial operating parameters to meet receiving water standards. o Incremental project costs due to additional operation and maintenance requirements (e.g. routine monitoring and reporting) Fiscal Effects on Local Governments: o Fiscal impacts would be project specific depending on net financial effects associated with this action. <u>Institutional</u> o Wetland treatment projects would require a facilities plan and discharge permit similar to treatment plants o Performance problems within artificial wetlands would be handled as treatment system malfunctions rather than as environmental catastrophes in a natural wetlands.	<u>Production of Goods and Services</u> o No impacts. <u>Income and Investment</u> o No impacts. <u>Consumer Expenditures</u> o Increased operation and maintenance costs, if any, may be paid for by user charges in multi-purpose facilities.	<u>Housing Supply</u> o No effects. <u>Physical Mobility</u> o No effects. <u>Health and Safety</u> o Standardized discharge criteria would ensure protection of public health in receiving waters. o Low-level public health risks may be associated with some parts of wetlands similar to treatment plants (unless mitigated by design conditions) <u>Sense of Community</u> o No impacts. <u>Urban Patterns</u> o No impacts. <u>Equity</u> o No impacts.

III. WETLANDS IN RELATION TO WATER QUALITY

The term "wetlands" is a general designation for low-lying lands where the water table is usually at or near the surface, or the ground is covered by shallow water. As defined by the U.S. Fish and Wildlife Service (Cowardin et.al., 1979), wetlands must have one or more of the following three attributes:

(1) the substrate is predominantly undrained hydric soil;

(2) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year; and

(3) the land supports predominantly hydrophytes.

Wetlands are complex ecosystems which are generally characterized by high plant productivity and nutrient needs; high decomposition activity; low oxygen context in the sediments; and large adsorptive areas in the substrates. These properties permit wetlands to assimilate large quantities of suspended and dissolved materials from surface waters. In a natural hydrologic system, wetlands can function to purify and maintain local water quality.

POLLUTANT REMOVAL MECHANISMS IN WETLANDS

Mechanisms for the interaction, removal and treatment of pollutants in waters can be divided into physical, chemical and biological (biochemical) processes. The following description presents the major treatment mechanisms. For a more detailed discussion of the mechanisms with specific examples of processing capabilities, refer to Technical Memorandum No. 69: "Wetlands and Pollutant Treatment Mechanisms."

Physical and Chemical Pollutant Removal Mechanisms

Pollutants enter a marsh primarily via surface runoff, groundwater inflow, or point source discharges. Other possible routes, such as aerial fallout, and mobilization of solid waste deposits within a marsh are generally minor although they may be significant in specific cases.

Surface runoff pollutants entering a marsh can occur in dissolved, emulsified, or particulate forms. Likewise, surface water flowing from a marsh carries pollutants in the same ways. These substances are not necessarily the same as the inflow pollutants. Many types of transformations occur in marshes and the products may leave the marsh. Pollutants can be removed by a wetland system through three main routes: loss to the atmosphere, incorporation into sediments or biota, and degradation. Some products of pollutant degradation may be inert or nontoxic, while others continue to pose environmental hazards. For example, some readily oxidizable organic compounds are quickly converted

to carbon dioxide and water. On the other hand, some pesticides are very stable or yield stable degradation products which are also toxic to the environment. Regardless of the nature of the products of pollutant transformations, they either flow out of the marsh, volatilize, or remain in the marsh--fixed in biota or sediments. A summary of the major pollutant removal mechanisms and the contaminants affected is presented in Table 3.

Biological Pollutant Removal Mechanisms

Vegetative systems possess a variety of mechanisms for obtaining nutrients and other elements from their environments under changing conditions. Through interaction with the various aerobic and anaerobic soil layers, water and air interfaces, plants can increase the overall capacity of a system to retain or remove pollutants. Since the primary mechanisms for pollutant removal in a wetland system are physical and chemical interactions that cause the contaminants to settle or be drawn out of the water column into the sediments, plant uptake of pollutants, particularly from the sediments, frees more exchange sites for further pollutant interaction and accumulation. Bacterial metabolism, in conjunction with physical sedimentation is probably an important mechanism in many wetlands. However, even in those systems, plants can provide surfaces for bacterial growth, filtration and adsorption of solids, attenuation of sunlight and nutrient absorption to retard growth of algae, and uptake of heavy metals.

The primary biochemical pollutant uptake and removal processes in vegetative systems are:

(1) Uptake through plant-soil interface, via belowground roots, rhizomes, holdfasts and buried shoots and leaves;

(2) Uptake through plant-water interface, via submerged roots, stems, shoots and leaves;

(3) Translocation through plant vascular system, from roots to stems, shoots, leaves and seeds during growing season;

(4) Differential pollutant uptake, such as preferential storage of trace contaminants in specific plant parts and preferential uptake/accumulation of certain trace elements;

(5) Nonspecific pollutant uptake, occurring primarily as plants absorb large quantities of nutrients from water and sediments;

(6) Uptake and immobilization by plant litter zones, where dead, but not decomposed, plant litter sequesters pollutants through chemical interactions.

TABLE 3. PHYSICAL AND CHEMICAL POLLUTANT REMOVAL MECHANISMS IN WETLAND AND AQUATIC SYSTEMS

	Pollutant Affected									
Mechanism	Settleable Solids	Colloidal Solids	Organic Compounds	Petroleum Hydrocarbons	Nitrogen	Phosphorus	Heavy Metals	Bacteria and Viruses	Halogenated Hydrocarbons	Description
Physical										
Evaporation			X	X			X[a]		X	Volatilization and aerosol formation
Sedimentation	X	X		X	X		X[b]		X	Gravitational settling of particles and adsorbed pollutants
Emulsification		X	X	X			X[a]		X	Suspension of chemicals that are sparingly soluble in water within an aqueous environment
Adsorption		X	X	X			X	X	X	Electrostatic attraction, Van der Waals force
Filtration	X	X						X		Mechanical filtration of particles through substrate, roots or animal systems
Chemical										
Chelation						X	X			Formation of metal complexes through ligands
Precipitation				X		X	X			Formation or coprecipitation of insoluble compounds
Decomposition			X	X	X	X	X	X	X	Alteration of less stable compounds by oxidation, reduction, hydrolysis or photochemical reaction
Chemical adsorption			X	X	X	X	X		X	Covalent bonding, hydrogen bond formation, hydrophobic interaction

[a] Significant only for mercury
[b] Not significant for manganese and mercury

Since the majority of waterborne contaminants are adsorbed onto particulate matter, sedimentation of particulates effectively scrubs the water column, and prevents dispersal of the pollutants. These organic-rich sediments are further bound in place by plant roots. The tendency for these sediment layers to become anaerobic is probably the major factor involved in the retention of various chemical species. Reducing environments allow the conversion of heavy metals into relatively insoluble sulfides and promote the removal of nitrate nitrogen through denitrification.

WETLANDS TREATMENT OF WASTEWATER

The planned utilization of wetland systems for wastewater treatment is a relatively recent innovation. Most of the current information on wetlands response to pollutants is derived from research activities on this application. Wastewater treatment seeks to utilize the following processes inherent in a natural wetland system:

(1) Sedimentation - water dispersion over a large area by hydraulic manipulation;

(2) Filtration - physical entrapment through screening and sorption in the surface soils and organic litter;

(3) Biological assimilation - uptake and metabolic utilization by plants; and

(4) Anerobic decomposition - utilization and transformation of material by microorganisms in the substrate.

In addition to the study of natural wetlands for wastewater treatment, artificial wetland systems have also been created to experiment with specific aspects of wetlands or to optimize specific treatment processes. These artificial systems rely also on one or more of the principles described for natural biological systems and also have the advantage that they can be easily manipulated and do not affect existing natural wetlands systems. Typically, the artificial systems are simplified wetlands that contain artificial substrates, cultures of predominantly one kind of vegetation and carefully-controlled conditions. However, some projects have been conducted on a larger scale with multiple-use objectives in mind such as environmental enhancement and habitat creation.

Table 4 presents ranges of removal efficiencies fo natural and artificial wetlands receiving primary- and secondary-treated sewage. In general, removal of organic material (BOD and COD) is very good. Nitrogen removal can be consistently high, but phosphorus removal is extremely variable and not reliable. Suspended solids removal is generally satisfactory, but can vary significantly with the hydraulic loading. Removal of heavy metal tons can also be effective in a wetlands. Under normal loadings of heavy metals in wastewater--which is

TABLE 4. WETLAND REMOVAL EFFICIENCIES FOR WATER POLLUTANTS

Pollutant	Removal Efficiency, %			
	Primary-treated sewage (artificial wetlands)	Secondary - Treated Sewage		Urban Runoff (natural wetlands)
		natural wetlands	artificial wetlands	
Total Solids		40 - 75		
Dissolved Solids		5 - 20		
Suspended Solids		29 - 90	0 - 92	87 - 99
BOD 5	59 - 90	70 - 96	37 - 92	54 - 97
COD	50 - 90	50 - 80		
Nitrogen (as N)	30 - 98	40 - 97	60 - 86	0 - 95
Phosphosus (as P)	20 - 90	10 - 97	77 - 97	37 - 99
Heavy metals		20 - 100	23 - 94	25 - 99

Source: Compiled from national case studies in: Chan, E., T.A. Bursztynsky., N. Hantzsche and Y.J. Litwin." The Use of Wetlands for Water Pollution Control," Association of Bay Area Governments. November 1981.

generally very light--uptake of this pollutant from the sediments by the plants is usually low. Examples of wastewater treatment case studies are presented in Technical Memorandum No. 77: "Wetlands Treatment Case Studies."

WETLANDS TREATMENT OF STORMWATER

Conventional stormwater management focuses on fast and efficient conveyance systems to remove stormwater from urban areas and facilities to minimize the inconvenience and hazard of excess stormwater accumulation.

Many wetlands have been receiving inadvertent discharges of stormwaters for a number of years. To date, there have been only a few instances where stormwaters have been specifically routed into natural or artificially-created wetlands for flood control or water quality management purposes. Where the practice has been employed, consistent reduction of BOD, suspended solids and heavy metals generally have been shown. Stormwater treatment through wetlands encompasses three categories:

(1) Systems planned primarily for flood control with treatment as an incidental benefit;

(2) Systems planned and operated with treatment of stormwater pollutants as a primary objective;

(3) Existing wetland systems providing detention and treatment of stormwater flows as an unplanned, natural function.

The factors responsible for wetlands treatment of surface runoff are largely the same as those noted previously in reference to wastewater treatment. In principle, wetlands offer hydraulic resistance to surface runoff flowing through them, resulting in decreased velocities and increased deposition of suspended sediments. The large surface area provided by surface soils and vegetation contributes to higher levels of physical absorption, adsorption, microbial transformation and biological utilization than normally occurs in more channelized water courses.

Table 4 presents ranges of removal efficiencies for natural wetlands receiving urban runoff. In general, removal of organic material (BOD) and suspended solids are consistently high, while nutrient and heavy metal removal vary from low to almost complete removal. Examples of urban runoff treatment case studies are presented in Technical Memorandum No. 77: "Wetlands Treatment Case Studies."

IV. THE FUNCTIONS OF WETLANDS IN THE BAY AREA

The previous chapter discussed one aspect of wetlands function: for water quality maintenance. Other beneficial roles that wetlands fulfill in the Bay Area include the functions of food chain, habitat, hydrologic and hydraulic, agriculture and recreation/open space. Many of these functions are complementary although not necessarily all functions reinforce each other.

FOOD CHAIN

The relationships between production and consumption of plants and animals begins with primary productivity. Soil, water and nutrient conditions promote plant growth through photosynthesis. Plant food supports another level of productivity through consumption of plant tissue or decaying plant matter (detritus). The food chain relationships continue as more plants and animals form an interrelated food web. Primary productivity in wetlands is generally high and even though material may be transported out of the system through surface flows, a healthy marsh usually produces abundant food and nutrients to support the system.

Marsh vegetation typically grows very densely allowing more plants per acre and greater productivity in comparison with wheat and other grain crops. Examples of characteristic vegetation include cattails and sedges in freshwater marshes, bulrushes in brackish water marshes, and pickleweed in salt marshes. Excess plant material, in the form of decaying detritus is often regularly or periodically flushed from the system and supports a continuing food web in a downstream community. For example, freshwater marshes contribute to downstream estuarine communities and tidal shoreline marshes help feed the Bay ecosystem.

Human activities such as diking, landfilling and water diversions can isolate a wetland community and greatly reduce its internal productivity as well as its contribution to external food chains. In the Bay Area, the historical diking of over 200 square miles of the original 313 square miles of tidal marshes drastically altered the baylands and reduced Bay productivity itself by curtailing the upstream food source. The remaining wetlands, however, do contribute indirectly to the Bay ecosystem. Plant matter is consumed by insects, worms and snails, which in turn are eaten by shorebirds and waterfowl. When these birds return to the Bay, the nutrients they have consumed eventually enter the Bay ecosystem.

HABITAT VALUE

Habitat refers to the place or situaation in which an organism spends part or all of its life cycle. Some ways of measuring the value of habitats are by diversity, extent and special function.

Diversity

The variety of plants and animals found in a particular area is often a good indicator of the health of an environment. High diversity implies that a community is well-developed with a complex food web that can accommodate many life-forms. The community can adapt to small-to-moderate changes and is relatively stable. Conversely, low diversity indicates that a community is poorly-developed or has relatively simple food web relationships that are susceptible to even slight perturbations.

The variety of habitats within a region are also an indicator of the health of an environment. Many wildlife species depend on one type of habitat for feeding, another for mating and yet another for nesting and breeding. The variety of wildlife species associated with wetlands depends also, in part, on the existence of ruderal or weedy upland areas and agricultural fields and alternate fresh, brackish and saline marshes. Urbanization tends to transform prroductive areas, such as wetlands and agricultural fields, into fallow upland areas with submarginal wildlife habitats. Enhancement and/or restoration of wetland habitats would be a valuable contribution to restoring former regional productivity.

Extent of Habitat

The amount of available habitats affects wildlife diversity and population size in the Bay Area. A particular habitat in short supply may be the determining factor in the sustenance of a healthy population, despite the abundance of alternative habitats. In the Bay Area, the extent of wetlands habitat has dwindled to critical amounts disproportionate to local and regional wildlife needs.

Indigenous, non-migratory species are particularly dependent upon habitat supply. For example, the salt marsh harvest mouse can only survive as long as it has an adequate supply of high, dry salt marsh.

Supply of habitat in the Bay is particularly important for migratory shorebirds and waterfowl. The large expanses of diked agricultural lands and diked brackish marshes of the Contra Costa shore of Suisun Bay provide for these species, on a smaller scale, the habitat formerly supplied by the large tidal marshes that used to exist near Alviso and in Napa County.

Small remnants of open land can also be important. Some smaller parcels serve as "wildlife oases" within urban areas. Animals tolerant of human activities can use these habitat islands. Skunk and raccoon are examples.

Special Functions of Particular Habitats

Some habitats provide multiple functions or may be critical to the survival of a particular plant or animal species. Baylands and wetland areas along watercourses and water bodies can serve several important functions such as providing transition zones, wildlife movement corridors, buffer zones or special necessities.

Whenever a wetland habitat occurs next to another type of habitat, the transition zone or ecotone is particularly important to wildlife. Plant and animal diversity is usually high due to the overlapping presence of species from the adjoining communities as well as some species that are characteristic of or restricted to the transition zone. For example, upland animal species will often come down to riparian and wetland areas for water and supplemental food. Birds and animals in intertidal habitats often depend on high ground transition zones when their normal habitat is inundated.

Watercourses and associated wetland habitats that traverse through or are adjacent to other habitats can facilitate wildlife movements. These corridors allow animal movement between habitats and are especially important for some species during various periods, seasons of the year or part of their life cycle.

Wetlands, particularly baylands, also function as buffers between natural habitats and encroaching urbanization. Some wildlife species are sensitive to habitat disturbances and need more "breathing space" or separation from human activities, to maintain their normal activities.

Lastly, some habitats provide special conditions that are vital to some species. Examples are breeding grounds where a specific substrate is required for egg-laying or nesting, nursery areas for juvenile animals, unique vegetation or other food sources or dependency on certain biotic relationships. For rare and endangered species, some of these special conditions are critical for survival.

HYDROLOGIC AND HYDRAULIC

Hydrologic and hydraulic functions of wetlands include damping floods, stabilizing shorelines or absorbing the destructive energy of storm waves, and recharging groundwater resources. Different types of wetlands vary widely in their ability to perform these functions.

Flood Control

Wetlands serve an important function for flood control in many parts of the Bay Area. They can operate as basins that both detain and retain flood waters--depending on wetland size, location and local hydrological characteristics. These "flood basins" are most effective during floods of high intensity and short duration. Extensive urbanization in the Bay Area has led to increases in non-porous surfaces with greater amounts of runoff and the use of storm drain systems to rapidly convey storm flows down the drainage system. The net result is that even low-to-moderate intensity storms can produce rapid and large volumes of runoff. When the downstream receiving areas--the flood plains and baylands--are filled or diked, water has less area over which to disperse and must pass directly into the Bay. If high volumes of water reach the downstream areas at the same time that the tides are high, there is no place for the water to go. Waters that were once dispersed over the high tidal marshes and flood plains then back up in stream channels and flood adjacent urban areas.

In this manner, the remaining diked, unfilled baylands and undeveloped flood plain areas are particularly valuable for flood control because they retain stormwater during coincident heavy runoff and high winter tides. Utilizing the flood control potential of these areas could, at times, require substantial modification or construction of both influent and effluent structures.

Shoreline Stabilization

Perennial and seasonal surface water flows as well as tidal water movements and wave action can erode and destroy unprotected shoreline areas. Wetland vegetation, especially those types with invasive roots and rhizomes can function to hold the substrate together and protect against scouring, wind and wave action. Where erosive forces are continously active--such as in tidal marshes with diurnal ebb and flood tides--the shoreline becomes established along a zone where new plant growth is effectively balanced or offset by erosion. San Francisco Bay is relatively protected against high velocity wind and ocean wave forces. Nevertheless, storm conditions can produce erosive activities in watercourses and large water bodies and predicate the need for some form of shoreline protection - such as along levees and dikes.

Groundwater Recharge

Wetlands, particularly perennial wetlands in upland areas, often are associated with high groundwater tables. Percolation of surface waters into lenses of sandy or other semi-porous strata can effectively recharge shallow or perched aquifers. However, not all wetlands recharge groundwater, and some actually discharge water, such as along shoreline areas.

AGRICULTURE

A majority of the diked baylands in the Bay Area are used for agriculture -- primarily to grow forage crops for dairy cattle. The BCDC "Diked Historic Baylands Study" recognized that even though the habitat value of diked agricultural lands is less than that of diked wetlands and tidal marshes, retention of these areas in existing uses is important. Agricultural areas provide greater habitat value than developed areas in the Bay Area and also help to buffer urbanized areas from diked wetlands and tidal marsh. In addition agricultural lands are important to the Bay Area economy because they provide low cost feed for dairy cattle and jobs.

Dairy farms of the north Bay provide about 50 percent of the milk and milk products that are consumed in the Bay Area. Forage for these dairies is grown almost entirely on diked historic baylands and sold to local dairies. Because feed costs are one of the largest expenses incurred by dairy farmers and because transportation costs make imported feed more expensive, use of locally grown feed is important to keeping costs down and the dairies in business.

The ratio of hay-oat farmers to dairies is critical. Each is dependent upon the other. A reduction in the number of dairies would mean hay-oat farmers would not have a market for their product. Likewise a reduction in acreage of forage crops would require more feed to be imported. Higher costs for dairy operators would result and could force some dairies to go out of business. This would be highly undesirable as most dairy farms and most hay farms are family enterprises and the farms themselves provide valuable open space. In addition, the dairy industry employs skilled and non-skilled workers on farms and in creameries and factories that manufacture milk products.

If farming is discontinued on the diked farmlands, they would most likely be developed into urban areas. The habitat and buffer values would then be lost.

RECREATION/OPEN SPACE

The baylands and remnants of floodplains and stream zones serve as open space. The open space function is especially evident in the north Bay where hundreds of acres of agricultural land can be seen from the major highways.

Some of the baylands are used for passive recreation. Most activities occur along the dikes and levees and at visitor centers at the 9 designated recreation areas in the baylands. The south Bay in particular offers opportunities for nature study, hiking, photography, birdwatching on diked baylands in Palo Alto, at the federal South Bay Wildlife Refuge in Alviso and Newark, and at the Coyote Hills Regional Park in Fremont. Many different types of groups including schools, scouts, Audubon Society and handicapped take advantage of the opportunities to view wildlife and study the Bay environment.

Active recreation such as jogging, hiking and riding is very popular along the trails that surround the baylands. This is because baylands are so near urban areas that people can use them much in the same way as their neighborhood park.

Although there is no accurate count of all who use the baylands for recreation and open space, the number is estimated to be over 100,000 per year (BCDC, 1982).

V. REGULATIONS AND AUTHORITY OVER WETLANDS DEVELOPMENT IN THE SAN FRANCISCO BAY AREA

The following section reviews federal, state, regional and local regulations and authority over wetlands development. An additional analysis is made to determine these agencies which would have authority over wetlands created for urban stormwater treatment and the extent of their jurisdiction. For a more detailed discussion of the various agencies and their authorities, refer to Technical Memorandum No. 88: "Legislative Requirements and Policies in the San Francisco Bay Area."

GENERAL AUTHORITY OVER WETLANDS

Many agencies at all levels of government have responsibilities for wetlands. The major permit authority over wetlands, granted under "Section 404" of the Federal Water Pollution Control Act of 1972 and to a lesser extent the Rivers and Harbors Act of 1899, is given to the Army Corps of Engineers. General guidelines under which the Corps should grant permits are established through federal directives and legislation. However, specific references to wetlands and permit granting criteria are to a large part incorporated in Corps and Environmental Protection Agency regulations rather than through congressional and executive decree. The general policy followed in granting a permit is that the project must be in the general public interest and that the project must be located in or near a wetlands with no feasible alternative site available.

Several federal agencies take an active part in the review process before the Corps will grant a permit. These agencies, such as the U.S. Fish and Wildlife Service, consider and evaluate the environmental effects of a proposed project. The Environmental Protection Agency can also withhold a permit should they find objections to a project requiring a "Section 404" permit. Other federal agencies participate as advisors to the Corps as projects come under their jurisdiction or mandate. All federal agencies must consider the requirements of the National Environmental Protection Act and Executive Order 11990 on protection of wetlands when reviewing projects potentially influencing wetlands.

While the Army Corps of Engineers is the major federal agency permitting wetlands activities, other federal agencies, noteably the Fish and Wildlife Service and the National Marine Fisheries Service, are more active as proponents of wetland development and restoration.

The State does not have strong regulatory authority over wetlands similar to the federal government. Permit authority is given to the Department of Fish and Game only in the event of streambed modification. The California Coastal Commission (CCC) holds permit authority over the ocean shoreline and to a lesser extent the San Francisco Bay Conservation and Development Commission (BCDC) grants permits for the

development of Bay shoreline. The State Lands Commission controls the use of certain lands that have not been obtained by private parties or groups. However, its authority is fairly limited and applies to a relatively small amount of land. Inland wetlands such as riparian zones bordering waterways and other potential wetlands are probably the largest areas lacking protection or jurisdiction by state agencies. The State Water Resources Control Board (SWRCB) and Regional Water Quality Control Boards (RWQCB) have powers and the mandate to ensure adequate water quality maintenance and protection in all waters of state. However, most of their activity has been directed toward dischargers rather than the active management of waterways to satisfy regional water quality objectives.

State agencies play an additional important role as advisors to permitting agencies. Under provisions of the Fish and Wildlife Coordination Act, the comments of the Department of Fish and Game are taken into consideration while reviewing permits for activities involving wetlands. Other state agencies may also comment on projects and provide important information regarding the public interest and possible environmental effects. State agencies frequently serve as a liasion enabling private groups to comment on proposed projects during the federal review process.

Local governments and special districts also play an important role in regulating wetlands. Considerable influence on the disposition of a wetland or potential wetland can be enacted through local zoning and planning ordinances and guidelines. Special districts often have control over sizeable land areas which may be amenable to multiple use including wetland development and maintenance. Local governments and special districts can play an active role as promoters of wetlands through both their standard policies and through active involvement on an individual case basis. However, many local jurisdictions have not adopted specific policies regarding wetland use.

While there are multiple and often overlapping regulatory powers over many aspects of wetlands use, with a fairly comprehensive review and comment system, there is little large-scale planning for the San Francisco Bay Area. Permits and comments are obtained on an individual project basis, frequently with little regard to the overall needs of the region. For example, selectively permitting development only on certain wetlands types, or allowing wetland mitigation to take the form of a consistent exchange of wetland types could result in an abundance of one type of wetland habitat at the expense of another. On a case-by-case basis, substituting one wetland type for another may appear to be in the public interest and not result in environmental degradation, but the diversity of available habitats to the entire region could be reduced. This activity could take the form of filling fresh and brackish water marshes while creating or expanding salt water marshes. Fresh and brackish water marshes support different communities than are found in salt water marshes, so excessive trade-offs of this nature could result in the loss of valuable species to the region.

AUTHORITY OVER SEASONAL STORMWATER TREATMENT WETLANDS

Jurisdiction over seasonal wetlands utilizing and treating urban stormwater runoff appears limited and highly variable. In developing, restoring or preserving wetlands receiving urban runoff, regulatory requirements will have to be evaluated on a case-by-case basis to determine permit requirements. Jurisdictional responsibilities may frequently be controversial since there is little precedent or legislation specifically addressing seasonal wetlands.

Federal jurisdiction over a wetland is most clear cut if the area is currently within the mean high tide of a tidal water, currently within the ordinary high water mark of a navigable river or lake, or is clearly an existing wetlands. Authority is somewhat uncertain over some areas below mean high tide if they are physically isolated from tidal action, such as diked wetlands. The Army Corps of Engineers has permit authority (under the Rivers and Harbors Act and/or Section 404 of the Clean Water Act) over any proposed site modifications of areas within this federal jurisdiction. The Corps currently has no comprehensive policy nationally or specifically for the San Francisco Bay Area regarding seasonal wetlands receiving runoff. Any plan for a seasonal wetlands would have to be evaluated on a case-by-case basis which gives no guidance in predicting the general acceptability of a project.

In an area with an existing wetland, it would be difficult to predict the response to a project proposal to utilize the area to treat urban runoff. The nature of the wetland might change from salt or brackish marsh to seasonally fresh, which would constitute a major change in habitat. It would be difficult to evaluate changes of this nature with regard to what best protects the general wetland resource and what is in the public good. Commenting agencies are likely to have widely different opinions; the National Marine Fisheries service would probably be more inclined to favor salt marshes while the California Department of Fish and Game may place a higher value on freshwater systems.

Federal permit authority generally would not extend over proposed sites for seasonal wetland development in upland areas that are currently not characterized as wetlands. Riparian zones, flood plains and historic wetland sites could potentially be developed without federal permission. Upland wetlands could be regulated as point source discharge points subject to NPDES requirements under the Federal Water Pollution Control Act.

The State of California has relatively little authority over the development of seasonal wetlands. The CCC and BCDC have permit authority over shoreline areas, but they have no general plan that accounts for seasonal wetlands. BCDC has adopted a policy, as a product of its "Diked Historic Baylands" study, regarding wastewater treatment projects using marshes or diked historic baylands. No BCDC policy exists specifically for stormwater runoff treatment projects." Similar to the problems with federal permitting of wetlands projects, there

exists no comprehensive plan from which to evaluate the value of a project with respect to existing wetlands and other land uses. The State Lands Commission has authority over tidal and submerged lands and beds of navigable waterways owned by the state, which may put some restrictions on wetland development. The California Department of Fish and Game regulates stream modifications which may occur in seasonal wetland construction projects. The SWRCB and RWQCB have responsibilities for the quality of the water in the State and implement the Federal Water Pollution Control Act. However, the State has relatively little power over the development of wetlands using urban runoff in upland areas. Perhaps more importantly, the State has no general policy controlling the quality of urban stormwater runoff which would provide incentives for wetland development.

Local governments, agencies and special districts can play a important role in wetland development and preservation. Potential wetlands under their jurisdiction or influence can frequently be managed for multiple use, including use as an urban stormwater treatment system. However, there is no general incentive for incorporating urban stormwater treatment into local planning. Treatment of stormwater serves to protect the health of the San Francisco Bay, with little observable immediate benefit to the local entity. No general plan exists that provides guidance regarding the needs of specific site development with respect to the overall environmental health of the region. Such a plan should be contained within the San Francisco Bay Area Basin Plan as administered by the RWQCB.

Currently, it is at the local level that the most opportunity exists for enhancement and creation of wetlands, particularly in upland areas.

VI. LOCAL POLICIES AND OPPORTUNITIES FOR WETLANDS DEVELOPMENT

The preservation, restoration and creation of wetlands are being actively promoted in the San Francisco Bay Area. The opportunity and incentive for wetland development appears greatest at the local and regional levels of government with federal and state agencies tending to serve primarily in a regulatory or review capacity. Special interest groups also play a major role in instigating wetland projects, often in conjunction with local and regional governments. Establishing urban runoff treatment wetlands is an innovative concept that generally has not been incorporated into planning activities. Policies and opportunities for local and regional involvement in developing wetlands are described in ABAG Technical Memorandum No. 89. A summary and conclusions from that paper are presented in this section to indicate the potential role of local and regional governments and special interest groups in developing urban runoff treatment wetlands.

AUTHORITY AND INTEREST

Local government jurisdiction to control land use is provided by the State Planning and Zoning Law and the Subdivision Map Act. The Subdivision Map Act gives the local government authority to cluster development to fulfill local planning goals. The State Planning and Zoning Law requires each local jurisdiction to adopt a general plan to serve as a guide for general development policies and land use objectives. Specific elements are mandated for inclusion in a general plan. Policies most likely to affect wetlands are generally found in the conservation, open space, recreation and seismic safety elements.

While local jurisdictions provide the general guidelines that can promote wetlands, it is often special districts and interest groups that initiate development. These groups generally function as advocates for wetland through lobbying activities to influence legislation and through support of specific projects. Activities in wetlands generally constitute only a small aspect of the concerns of most environmental groups. The "Wetlands Coalition" provides a forum and centralized information source for those groups with strong interests in wetlands in the Bay Area.

COUNTY GENERAL PLANS

Counties recognize in various elements of their general plans the value of wildlife habitat, open space, recreational opportunities, and other features offered by a wetland. However, little or no mention is given to the potential value of wetlands in improving water quality to the Bay. To be successfully established, a treatment wetland would probably have to be promoted on the basis of its multiple use functions.

Implementation of plans recognizing wetland establishment as a means of fulfilling multiple objectives is often difficult. Financial

mechanisms for acquiring, developing and maintaining wetlands are limited, and general plans do not offer schedules for obtaining funds. At worst, general plans may simply be identifying many of the values associated with wetlands, with no real attempt being made to accomplish these goals. However, the recognition of the values of wetlands coincident with local government goals offers the opportunity for interest groups to strongly promote establishment or preservation of wetlands within an existing government framework.

REGIONAL PLAN

The Association of Bay Area Governments (ABAG) functions as a planning agency encompassing the entire Bay Area region. The ABAG Regional Plan incorporating its Environmental Management Plan (EMP), contains elements important to considerations of wetland creation and restoration. Regional planning allows local governments to develop their general plans to be consistent with regional goals and neighboring communities. Many of the county general plans make reference to the ABAG Regional Plan as a guiding document.

The major components needed to support wetland activities are identified in the ABAG plan but there is no general recognition of the value of wetlands in fulfulling goals from various parts of the Plan. However, the EMP does call for the establishment of a program of low cost surface runoff controls that recognizes the need for water quality protection of the Bay missing from most county plans.

SPECIAL INTEREST GROUPS

Special interest groups can play a valuable role in offering measures to mitigate possible adverse affects of development. Interest groups can be particularly effective in monitoring and evaluating a site to determine both possible impacts of development and the success of mitigation measures.

While environmental groups usually are not able to finance wetlands projects directly, they may arrange for financing from developers, government, and any other likely source. Special interest groups are frequently the chief proponents of wetland projects and play an important role in seeing that government fulfills its responsibility.

VII. MECHANISMS FOR WETLANDS CREATION AND ENHANCEMENT

The values of wetlands and the local commitment to wetland preservation, restoration and creation have been documented throughout the Regional Wetland Plan. However, mechanisms to implement wetland projects are fairly complex and ordinarily require participation from a number of agencies and other interested groups. Authority, policies and opportunity for federal, state, regional and local involvement in developing wetlands have been described in ABAG Technical Memoranda 88 and 89. Potential funding sources and procurement mechanisms applicable to wetlands projects in the San Francisco Bay Area have been identified in ABAG Technical Memorandum 91. This section contains a summary and integration of these technical memoranda to show practical mechanisms for wetlands creation and enhancement.

FINANCING MECHANISMS

Means of financing projects to restore, acquire and develop wetlands, while limited, often are available for worthwhile and effectively promoted projects. A useful approach to successful project implementation is to try to minimize costs rather than maximize financial commitments. Land may be acquired at low cost through various incentive and mitigation schemes, or through the multiple purpose use of lands now dedicated exclusively to single activities such as flood control. Some system management may be available through the use of volunteer efforts from interest groups. However, some real financial commitment is unavoidable and remains the most significant obstacle to many wetland development projects. The various major programs for obtaining funds for wetland development are summarized in Table 5.

The U.S. Fish and Wildlife Service (FWS) has been active in protecting wetlands nationally and specifically in the Bay Area. The National Wildlife Refuge system operated by FWS has been authorized to purchase 22,947 acres of land and open water in the South San Francisco Bay Area. They have also contributed to the planning and design of a new fresh and brackish water marsh system at the Hayward Regional Shoreline Marsh. Other federal agencies and programs support wetlands, although they usually are not able to make a financial commitment in this region.

Some state funding is available for wetland acquisition and development projects. The State Resources Account, the Kapiloff Land Bank, and the California Coastal Conservancy all have funds that can be made available for wetland projects. Other state agencies encourage wetland projects, and may prove valuable in recommending mitigation techniques or desired land use that may lead to the dedication of lands for wetland use.

Local governments can finance wetland acquisition and development projects directly or through agencies such as park or flood control districts. However, local governments generally have very limited

TABLE 5. SUMMARY OF MAJOR POTENTIAL FUNDING SOURCES FOR WETLAND PROJECTS

Funding Source	Program/Authorization	Previous Activity and/or Funding Availability
U.S. Fish and Wildlife Service	Migratory Bird, Land Acquisition Program	2.2 million acres of habitat acquired between 1935 and 1976; none in Bay Area.
	Land and Water Conservation Act	Authorized 22,947-acre National Widlife Refuge in South San Francisco Bay Area. 100,000 acres acquired nationally through 1977.
	Local assistance	$25,000 toward marsh expansion in Hayward
Agricultural Stabilization and Conservation Service	Water Bank	585,000 acres protected by 1979. None in Bay Area.
State Treasury Account	Environmental License Plate Fund	Funds vary yearly; dedicated to environmental uses.
State Lands Commission	Kapiloff Land Bank Act	Authorized September, 1982.
California Coastal Conservancy	Public Resources Code Section 31054 et. seq.	$2.2 million allocated for San Francisco Bay Area.
Local Governments	Implementation of city/county general plans	Land purchase and leasing, e.g. Coyote Hills in Fremont.
	Park Districts	Development of wetlands parks, e.g. Coyote Hills in Fremont.
	Flood Control Districts	Several, including flood basin at Coyote Hills in Fremont leased by Alameda County to develop wetlands.
Private developers	Mitigation or philanthropic	Several, including Muzzi Marsh, Marin County; Faber Tract Basin, Palo Alto.
Special Interest Groups	Funding limited; provide services	Numerous
Foundations	Various	Largely Untapped.

capability to finance wetland projects following the passage of Proposition 13 in 1978. Mechanisms are available for local government acquisition of lands at below market price, depending to a large extent on offering tax advantages for the gift or favorable sale of a wetland or potential wetland.

Private developers may be induced to develop wetlands as mitigation measures. In accordance with the California Environmental Quality Act, measures to mitigate potentially adverse environmental impacts must be included in the project Environmental Impact Report. Permit requirements may include funds for restoration and development, as well as land acquisition.

Acquisition and development of wetlands may also be financed through donations from private foundations. Several foundations in the Bay Area have policy objectives to support activities enhancing the environment. Although foundations historically have not played a major role in wetland activities, they may represent a largely untapped source of funding.

COORDINATION MECHANISMS

Financing of a wetland is unlikely to come exclusively from a single source. Coordination between several interested parties is usually required to successfully establish a wetlands. Additionally, development and approval of a wetland project usually requires active participation of a number of agencies and interest groups without a direct financial commitment. Scenarios indicating how various groups could effectively interact to promote wetland activities is shown in Table 6. A vital element not specifically shown in these scenarios is the efforts of an effective project proponent overseeing and coordinating development activities.

CASE STUDIES

The development of a wetlands has been identified as a relatively complex procedure, requiring considerable efforts with limited financing. However, proponents of wetlands should be encouraged by the recent construction of several wetlands in the Bay Area indicating the feasibility of development. Two such projects have been described previously in support documentation prepared as part of ABAG's Regional Wetland Plan. The Coyote Hills Demonstration Urban Stormwater Treatment marsh in Fremont was constructed to treat urban runoff, to serve as a test facility for examining the effectiveness of wetland treatment, and to expand the regional park system. The Hayward Shoreline Marsh Project forms a key part of the 1800-acre coastal restoration master plan of the Hayward Area Shoreline Protection Agency (HASPA). The project activity sequence for the Coyote Hills Demonstration Urban Stormwater Treatment Marsh is shown in Figure 1, representing a successful wetland development scenario.

TABLE 6. SCENARIOS FOR WETLANDS CREATION AND ENHANCEMENT

Activity that could produce wetlands	Participants	Rationale and/or Justification
Development of recreation areas: 1. wetlands park 2. pond/marsh sub-components in a park 3. urban trails/bikeways along riparian corridors 4. pond/marsh subcomponents in a golf course	o Cities and counties o Park districts o Recreation associations o Homeowners associations o Special interest groups	Multi-purpose planning--wetlands could provide urban runoff treatment, focal or highlight points for recreation areas
City/County General Plans-maintenance of special use or high development risk zones such as: 1. waterways and floodplains 2. unstable clay soils 3. airport hazard zones 4. wildland fire hazard and fire breaks 5. stream conservation 6. open space	o Cities and counties o Special districts (e.g., public works, flood control, fire department, park districts)	Wetlands creation can be compatible with some types of special use/risk zones due to: 1. similar habitat (streams, waterways and floodplains 2. complementary use - fire protection 3. coincidental use - open space areas, airports, etc. where wetlands would not interfere with normal uses.
Flood control, flood prevention and water supply facilities: 1. floodwater retention basins 2. flood channels (unlined) 3. impoundment basins 4. Channel dredging and disposal of dredge spoils	o Flood control districts o Water utility companies o Landowners o Special interest groups	Seasonal/permanent wetlands use can be compatible with: 1. low-flow or low-water conditions 2. short-term high water conditions 3. channel bank/bottom protection 4. lakes, ponds, unlined basins Flood control districts usually have long-term capital improvement programs where wetlands creation projects may be incorporated.

TABLE 6 (Continued)

Activity that could produce wetlands	Participants	Rationale and/or Justification
Abatement of urban runoff pollution in waterways storm sewers or water bodies	o Cities and counties o Regional Water Quality Control Board (RWQCB) o Large land development project owners/operators	RWQCB could require a local entity to reduce urban runoff pollution to Bay from their watershed. Local jurisdictions could choose wetlands treatment as a low-cost clean-up method.
Construction of a wetlands treatment system for combined municipal wastewater and stormwater.	o Local sanitary districts o Regional Water Quality Control Board	A sanitary district may choose wetlands treatment as a alternative low-cost facility.
Planning/implementation of erosion control plans with features such as: 1. sedimentation basins 2. retention/detention basins 3. temporary/permanent waterways, swales and dikes	o City/county public works department o Land development companies o Local landowners o Building/grading contractors	City/county grading ordinances often require erosion control plans for multi-unit development projects and public works projects. Semi-permanent wetlands could be incorporated into some types of erosion control measures that are compatible with final development.
Industrial/commercial/residential landscaping with features such as lakes, ponds, waterways, etc.	o Land developers o Landscaping contractors o Homeowners associations o Landowners	Water-oriented landscaping features, improve land values, provide focal points, aesthetic enhancement and also can receive and process urban runoff.
Commercial resource developments such as 1. duck clubs-hunting areas 2. pheasant farms 3. aquaculture-fisheries, algae, invertebrates, etc.	o Landowners o Recreation associations o Commercial groups	Some types of commercial resource developments require seasonal, partial or permanent flooding of land to create suitable growing habitat. Surface runoff can be used as a water source and wetlands are often compatible with these uses.

TABLE 6 (Continued)

Activity that could produce wetlands	Participants	Rationale and/or Justification
Shoreline development	o Bay Conservation and Development Commission o Army Corps of Engineers o Wildlife agencies o Cities and counties o Land developers	All shoreline activities require one or more permits. Activities affecting existing/historical wetlands often require wetlands restoration or enhancement to mitigate negative project impacts.
Improvement of shoreline environment for aesthetic value and recreational use	o Local jurisdictions o Park districts o Recreation associations o Special interest groups including conservation groups	Wetlands creation within shoreline zone could satisfy many purposes: 1. urban runoff treatment 2. environmental enhancement 3. wildlife habitat enrichment 4. recreational enjoyment
	o Local jurisdictions o Private developers	Local jurisdictions may encourage/require shoreline development projects to incorporate water-oriented facilities design.
Creation of wildlife refuge areas and nature preserves	o Wildlife agencies o Park districts o Cities and counties o Special interest groups o Conservation groups (e.g., Coastal conservancy)	Waterfowl refuges and marsh preserves require wetlands incorporation. Surface runoff can be used to enhance or maintain wetlands
Creation of special educational facility at a wetlands with observation platforms, special displays, laboratories or trained personnel	o Local jurisdictions o School districts o Special interest groups o Park districts o Natural history museums	Wetlands could be created or enhanced to provide a "living museum" of "outdoor classroom" for students
Research on wetlands processes or special aspects within wetlands	o Academic institutions o Research foundations and groups o Special interest groups	Wetlands can be created or modified to meet specific research objectives or to provide a wider range of study conditions.

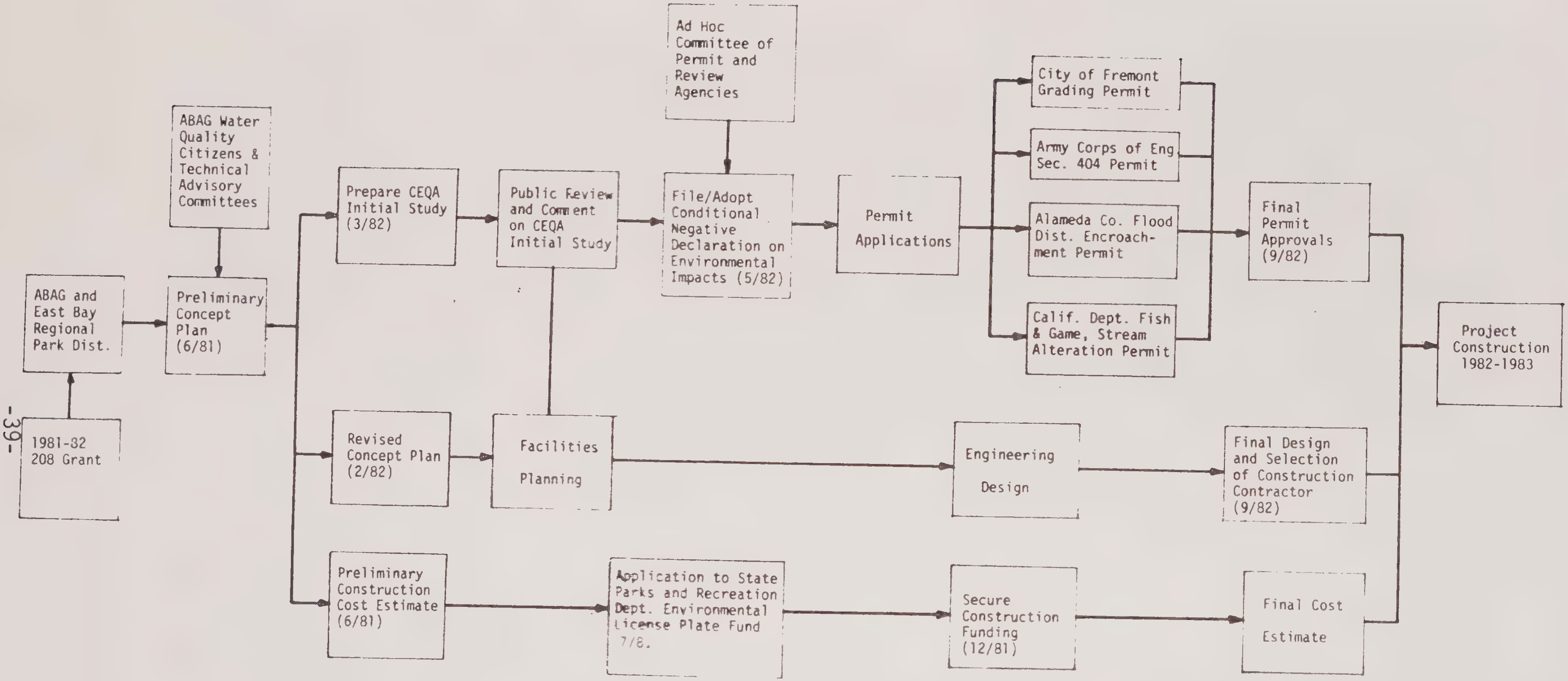

FIGURE 1. PROJECT ACTIVITY SEQUENCE, COYOTE HILLS DEMONSTRATION OF URBAN STORMWATER TREATMENT MARSH

CONCLUSIONS

A major environmental objective common to various levels of government, interest groups and individuals is the preservation, restoration and creation of wetlands in the San Francisco Bay Area. The greatest obstacles to wetland development are often the lack of financial support and the lack of coordination between groups supporting varied interests. However, these obstacles are not insurmountable, and can be overcome through a variety of activities and cooperative efforts. Wetlands have been successfully developed recently in the region, including the wetlands at Coyote Hills in Fremont designed specifically to treat urban runoff and test treatment effectiveness. The long term success of plans to enhance the wetlands resource in the Bay Area will ultimately depend on the efforts of wetland proponents to overcome obstacles and to creatively use available resources. The mechanisms described in this plan show how objectives for wetlands can be accomplished.

VIII. GUIDELINES FOR SELECTING POTENTIAL WETLAND TREATMENT SITES

The suitability of a site for wetland development depends both on an intrinsic ability to support wetland habitat (without requiring substantial and costly modifications) and a favorable socio-economic and political climate supporting wetland land use. The efforts of strong and enthusiastic project proponents are a vital part of any plan to develop or preserve a wetland. The criteria listed below can be used to assess the suitability of a site for wetland development. Descriptions of each criterion in this section should provide guidance for proponents of specific wetland projects.

Hydrologic and water quality factors:

- urban runoff treatment needs
- water supply
- influent water quality
- effluent water quality

Physical and environmental factors:

- compatible topography
- substrate suitability
- environmental sensitivity

Socio-economic and cultural factors:

- current land use
- potential for multiple use
- land availability
- legal constraints
- funding and cost-effectiveness

HYDROLOGIC AND WATER QUALITY FACTORS

Urban Runoff Treatment Needs

Urban runoff is a significant source of pollution to the San Francisco Bay System as identified in Section I of this Plan. Surface Runoff Management Plans prepared for each county in Appendix C of the Environmental Management Plan as well as subsequent ABAG water quality technical memoranda recognize problem areas associated with natural drainages and water bodies. Quantification of water quality impacts for the entire Bay Area would be difficult and costly to perform on a site-specific level. However, based on pollutant levels observed in research studies conducted in San Jose and Castro Valley, it can be substantially assumed that all urbanized areas in the Bay region contribute water quality pollutants that can degrade the local environment. Greater density and extent of urban area tributary to a drainage system also lead to higher pollutant generation and greater

treatment need. Thus, potential wetland treatment sites located downstream of an urban drainage area would have greater clean-up value than sites located in sparsely developed areas or drainages receiving only minor amounts of urban runoff.

The environmental sensitivity of the receiving waters below an urban drainage area is also another important consideration for runoff water treatment needs. Receiving waters that offer low dilution potential, poor circulation and flushing, or that support sensitive communities such as shellfish populations would probably benefit from pretreatment of the incoming waters. Wetland treatment sites situated to intercept urban runoff waters and provide some level of pollutant removal would serve to protect vulnerable downstream receiving waters.

Water Supply

An obvious requirement for the creation of an urban runoff treatment wetland is local source of runoff. If the conveyance of runoff to a site requires the construction of pipelines, channels and pumping facilities, costs will probably be prohibitive for wetland development. Favorable sites will ordinarily be located along existing or planned stormwater conduits.

A wetland receiving runoff as its sole water supply will have considerable variation in water availability. While a low flow may be maintained during the dry season from sources such as local irrigation, portions or all of the wetlands may be expected to become dry part of the year. However, seasonal variation with high flows during the winter and an extended dry period during the summer does not preclude wetland development. Historically, the freshwater wetlands surrounding the Bay were adapted to these conditions. Numerous types of vegetation which senesce during long dry periods are able to quickly rejuvenate and thrive after a rain. Annual vegetation dies during the summer, but produces sufficient seed to reestablish the population during the fall. Fall and winter migratory waterfowl find this type of habitat very useful, and many local wildlife populations are able to use this type of variable habitat.

Urban runoff treatment wetlands can also be fed by sources other than surface runoff. Urban drainages often follow natural drainages, which may have a perennial base flow or may be dry for only a short period during the summer. Treatment wetlands may also be developed on areas with high groundwater tables, which provide a perennial supply of water to marsh vegetation and maintain ponded water in swales and depressions. Different types of habitat would be established at marshes that are wet perennially from those that are wet only seasonally. However, the potential for water quality enhancement is apparent under both conditions, and both would offer the habitat values associated with wetlands.

Brackish water treatment wetlands could be developed along some Bay tidelands. However, tidal wetlands, receiving freshwater input either seasonally or for a short period following precipitation, would present an environment with dramatic fluctuations in salinity. This would probably favor establishment of vegetation with wide salinity tolerances such as pickleweed (Salicornia virginicu) and alkali bulrush (Scirpus robastus).

Influent Water Quality

Two types of water sources can be considered for application in treatment wetlands: treated wastewater and surface runoff water. Other water sources, such as ground water, are generally not used in this type of system or do not have significant treatment needs. The predominant pollutant constituents would determine the treatment needs and indirectly the system size and type.

For a detailed discussion and comparison of wastewater and urban runoff quality, refer to "The Use of Wetlands for Water Pollution Control" (Chan et.al., 1981). The most commonly encountered wastewater treatment stages are (1) primary--where sedimentation removes the bulk of settleable solids and a portion of organic matter and (2) secondary--where biological oxidation produces significant reduction in the balance of the organic matter. Variations in the treatment processes can be targeted at specific wastewater constituents such as suspended particulates, colloids, organic matter, nutrients, toxics, pathogens and dissolved salts. In the Bay Area, municipal wastewaters typically require at the minimum secondary treatment, although some industrial discharges with small or intermittent flows are treated only to the primary level. Secondary wastewater typically contains low but continuous concentrations of organic matter, heavy metals and bacteria, along with high levels of nitrogen and phosphorus and in particular, nitrogen in the ammonia form--which is deleterious to aquatic communities. Wastewater flow volumes are relatively uniform but may vary seasonally depending on industrial activity and population shifts.

Urban runoff, on the other hand, can fluctuate dramatically in flow and pollutant concentrations. Typically, the initial runoff from a storm flushes out pollutants that have accumulated during the previous dry period. Thus, the first flush from each storm event can carry extremely high levels of suspended solids, bacteria, organic matter, phosphorus, hydrocarbons, and some heavy metals. However, subsequent levels in later flows are greatly attenuated and disappear when the stormwater flow subsides. During the dry season, a similar cycle occurs where pollutants accumulate in the storm drain system and flow events triggered by landscape irrigation and other human activities cause "mini-flushes" of pollutants. With these considerations, wetlands designed to receive urban runoff must be able to withstand initial pollutant shock loadings, and be of sufficient size with provisions for dredging access to handle sediment accumulation.

Effluent Water Quality

Overall, wetland treatment systems can be expected to improve local water quality and the system discharges should not harm the environmental sensitivities of the receiving waters. However, the effluent water quality can change seasonally, depending on internal wetland mechanisms.

Wetland treatment mechanisms are affected by climate variations and become more active at different times of the year. Specifically, plants are most active during the growing season and biological uptake would be higher during that period. Extremely cold weather would inhibit plant and microbial activity leaving the physical mechanisms such as sedimentation and precipitation as the primary treatment processes.

Hydrological conditions can cause short-term degradation of system water quality. Extremely high flows, such as during a major storm or flood event, can lead to turbulent water conditions and scouring water velocities. Sediment and some pollutants deposited in a wetland system may be resuspended and conveyed to downstream receiving waters, causing environmental damage. It should be noted however, that stormwater runoff -- particularly from a major storm or flood event -- carries high pollutant loads and the increment contributed from a wetland may be hard to determine.

Seasonally-related biological activities in wetlands can also cause short-term water quality degradation. In the spring and summer, the warming of surface waters and the lengthening of the photoperiod can trigger periodic algal blooms that deplete waters of nutrients, inorganic carbon and some minerals. Subsequent algal die-off can lead to short-term decreases in dissolved oxygen and odor problems. However, these effects are temporary representing little threat to receiving waters and are a favorable trade-off for the regular reduction of pollutants in the effluent waters.

Standards governing stormwater runoff quality are not included in the Basin Plan of the Regional Water Quality Control Board and no other specific criteria are available to evaluate system effectiveness in improving water quality.

PHYSICAL AND ENVIRONMENTAL FACTORS

Compatible Topography

One of the most obvious characteristics of wetlands are their tendency to form in "sinks" or low-lying areas. Thus, wetland formation requires shallow-to-deep land depressions and if peripheral marshes are desired around an open water body, then shallow areas where the water would be less than 3-ft deep are necessary.

If a wetland is to be artificially created on a site, then earthwork such as grading of shallow and deep areas, islands, drainage channels and berms may be employed. In this case, the absolute flatness of the land is not a requirement, since the amount of cut and fill in the landscape design can compensate for topographical irregularities. Nevertheless changes in major topographical features such as mounds, hills and ridges can be costly and may render a site unfeasible for wetland creation.

Substrate Suitability

Both the physical and chemical nature of the substrate need to be examined to determine if it is suitable for wetland vegetation. If only minor modifications are to be done to the site, and a healthy vegetation cover is currently present, wetland vegetation should reestablish quickly following inundation. If a large amount of earth moving is necessary, some care should be given to examining the soil or subsoil to be used or exposed as marsh surface.

Harvey et.al. (1982) describe some of the soil conditions that affect the establishment and health of wetland vegetation. Loose loam to clay soils are identified as best for marsh plant growth, although dry, cracked clay (and silty) soils may require several weeks of water exposure to become resaturated before planting. Sandy and gravelly substrates are identified as unfavorable because of the lack of nutrients and the poor rooting zone, respectively. Peat soils are also identified as unfavorable because of poor nutrient absorption, water exchange, and high acidity. Chemical conditions conducive to wetland vegetation establishment and growth include a soil with sufficient available nutrient supply (depending to a large extent on appropriate pH). Salinity will play a major factor in determining the type of vegetation that will become established. The availability and form of trace minerals and other growth elements will also be important factors affecting vegetation establishment, although little is known regarding effect of disturbance on marsh soil fertility.

Environmental Sensitivity

Favorable sites for wetlands development could occur over a variety of natural or modified habitats. Sites that have been extensively altered by human activities (e.g., barren or "waste" places) would have low habitat value and could be improved through wetlands development.

Sites with existing habitats that are in abundant supply (e.g., pasture) or degraded habitats that were formerly very productive (e.g., disturbed marsh areas) can be suitable for wetlands enhancement or development. Whereas the existing habitats retain some marginal-to-useful value, the trade-off achieved by wetlands development would be the augmentation of a vital and productive habitat in short supply.

Sites with existing natural habitats require a more careful evaluation of site-specific and local environmental sensitivities. Where possible, care should be taken to preserve and protect sensitive habitats such as healthy, productive wetlands, riparian vegetation, important wildlife breeding, nesting or feeding areas and critical habitat areas for rare or endangered species. Consultation with local wildlife agencies and wildlife support groups can help to define the sensitive areas and delineate measures for protection or impact mitigation. Where natural habitats may be affected by project developments, adequate habitat recreation or compensation should be considered.

SOCIO-ECONOMIC AND CULTURAL FACTORS

Current Land Use

A favorable site for wetland development should be relatively free of large structures and trees. The history of the area should be known to ensure that hazardous wastes have not been deposited on the site that could be uncovered and mobilized in the environment through marsh creation activities. Types of existing land use that are compatible with wetland creation include:

- Existing wetlands - particularly seasonal wetlands and areas with degraded habitats
- Pasture lands
- Agricultural lands excluding orchards
- Ruderal areas - disturbed and waste areas (such as road sides), abandoned pasture and agricultural lands with weedy vegetation
- Barren areas - waste areas with little or no vegetation (further investigation may be required to determine if the cause for the current lack of vegetation will present obstacles to wetland vegetation establishment).
- Marginal or interior areas with one or more of the above uses that exist within other land uses such as residential, commercial, industrial, parks, utility right-of-way or upland areas.
- Flood control lands

Potential for Multiple Use

The creation, restoration and preservation of wetlands in the Bay Area is a goal common to many individuals, groups and local governments with primary consideration given to goals other than improvement of stormwater quality. A program creating treatment wetlands should comprise only a subset of a comprehensive Bay Area wetland program.

In most cases, the justification of a site for use as a wetlands will be successful only if it is promoted on the basis of the many benefits that will be provided, with water quality enhancement simply representing one of these benefits.

A comprehensive discussion of the many benefits provided by wetlands is beyond the scope to this study. Reviews of the basic values and functions of wetlands are available in many documents, including recent reviews by Larson (1981) and Greeson, et. al., (1979). Multiple-use values commonly associated with wetlands include:

- wildlife habitat
- high productivity
- flood control
- diverse ecosystem
- recreation (contact and non-contact sports)
- education
- fish nursery
- groundwater recharge
- aesthetics

Evaluations of site suitability should include considerations not only of the values that a proposed wetland can supply, but the accessibility and need of those values. For example, much of the remaining wetland around the Bay is tidal so the development of freshwater wetlands would offer a habitat now of very limited availability in the region. Similarly, a remote, inaccessible wetland will have less educational value than a wetland neighboring an urban community with easy access. However, site evaluations may also result in conflicting results. A wetland offering open space and visual relief in an urban setting would present greater benefits (measured in terms of number of beneficiaries) than a remote wetland that was not available for viewing. However, a remote wetland would usually offer better habitat than one in an urban setting.

Land Availability

The availability of land for possible development into a treatment wetland should be evaluated at a very early part of project investigation. Sites designated for urban development would often be prohibitively expensive to acquire.

Since lack of financial support often limits the success of wetland projects, implementation of a plan is frequently dependent on acquiring lands for free or at very low cost.

Several techniques should be employed in determining the availability of a site. Zoning maps should be examined to determine allowable uses of the land. Land owners have to be identified and questioned with regard to their plans for the site, and their willingness to donate or sell (and at what price). Neighboring areas have to be considered with regard to the effects and acceptability of the wetland project.

Legal Constraints

An evaluation of the suitability of a site for wetland development should include considerations of possible legal constraints. Several agencies such as the Army Corps of Engineers and California Department of Fish and Game have permit authority over wetland projects, although authority will vary considerably depending upon location and site specific conditions. Discussion with involved groups and permit agencies at an early stage of project planning should be useful in determining if obstacles to wetland development may exist that could ultimately stop the project.

Care must also be taken in project planning to verify the legal standing of the involved parties. For example, funds can be obtained only by specific parties from the California Resources Account, so any plan for obtaining funding from this source must go through an eligible recipient. The ownership of bayshore lands are frequently in dispute, so great care must be made that negotiations for land be conducted with all interested parties.

Funding and Cost-Effectiveness

Obtaining adequate funding is critical to the success of a wetland development project. The ease of obtaining funds can vary significantly depending on the location and nature of a site.ding ssources will review projects with regard to the value of the proposed project against alternative uses of the funds. Furthermore, certain areas have funding sources that are restricted or motivated to using funds only in those areas, such as the BUCK Foundation in Marin County.

Cost-effectiveness is an important consideration in maximizing the development of treatment wetlands in the Bay Area. Projects which can be implemented, operated and maintained at relatively little cost should be encouraged. Considering the large potential for developing treatment wetlands, it appears practical to first use available resources to develop as comprehensive a treatment wetland system as possible, and reserve very costly individual systems for later efforts. Of course, if other conditions strongly indicate the need for a wetland in a specific site, such as an overriding concern to offshore biota from a particular runoff discharge, considerations of cost-efficiency may be subjugated to those of need.

CONCLUSIONS

Selecting sites for urban runoff treatment wetlands requires consideration of a large number of criteria. Evaluations need to be conducted regarding the physical and chemical suitability of a site, and the degree of engineering and construction that would be necessary for development. The need and usefulness of a wetlands location should be determined with respect to specific site locations. Socio-economic and political considerations also are major concerns governing the evaluation process, and strongly influence project funding. A site must

be acceptable to the many individuals and groups interested in wetlands, and often must be actively and effectively promoted to result in implementation.

A comprehensive evaluation used in selecting a site for the development of a treatment wetland can greatly reduce the efforts needed to implement development plans. Problems can be foreseen and the practicality of a particular plan assessed. Adequate site selection can reduce incidences of putting substantial work into a project, only to discover at a relatively late date that an unresolvable problem will make development impractical. A key to adequate site selection is that input must be obtained at a very early stage from all interested parties to determine project feasibility, and to compare the relative value of particular project with alternatives.

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APPENDIX A

WATER QUALITY TECHNICAL MEMORANDA

The following technical memoranda were prepared as support documents for the Regional Wetlands Plan for Urban Runoff Treatment. A summary of each technical memorandum is presented below. Copies of the entire technical papers are available from the ABAG Public Affairs Department.

No. 69 "Wetlands and Pollutant Treatment Mechanisms," by T.A. Bursztynsky and E. Chan. September 1981. 56 pages.

Reviews types of wetlands and their capabilities for wastewater and stormwater treatment. Discussions and examples of physical and chemical pollutant removal mechanisms are given as well as vegetative pollutant uptake processes. The text includes several tables on reported removal potentials of selected emergent, floating and submerged plants on nutrients, heavy metals and other pollutants.

No. 77 "Wetlands Treatment Case Studies," by E. Silveira and E. Chan, November 11, 1981. 29 pages.

The status of 10 existing marshes in the Bay Area is reviewed--nine of which presently receive urban runoff and one of which receives wastewater. Data on pollutant removal effectiveness is given for two of the marshes. In addition, short case studies are given for four southern California marshes, five marshes in the U.S. treating wastewater and four marshes in the U.S. treating urban runoff.

No. 88 "Legislative Requirements and Policies in the Bay Area," by G. Silverman, December 2, 1982. 23 pages.

Reviews legislation and authority over wetlands development for federal, state, regional and local agencies with discussion on the federal Section 404 and Section 10 permits administered by the U.S. Army Corps of Engineers.

No. 89 "Policies and Opportunities for Local and Regional Involvement," by G. Silverman, December 2, 1982.

The various elements of each county general plan in the Bay Area are reviewed for authority and interest in wetlands development projects. The policies of the ABAG Regional Plan and various special interest groups are also reviewed with respect to sponsoring wetlands projects.

No. 91 "Funding Mechanisms and Potential Funding Sources in the San Francisco Bay Area," by G. Silverman and E. Chan, December 2, 1982.

Potential funding mechanisms and sources are identified for existing federal, state, local and private funding sources. Scenarios of various potential wetland creation projects and funding case studies of two successful wetland development projects in the Bay Area are also given.

No. 92 "Case Study of Marsh Planning, Design and Creation: Hayward Shoreline Marsh - Phase II," by Emy Chan, December 2, 1982.

The development sequence of a 140-acre fresh and brackish water marsh creation is reviewed including descriptions and discussions of the system hydraulics, water supply, operation and management plan, environmental review and permit procedure, project costs, sponsors and funding.

No. 93 "Case Study of Marsh Planning, Design and Creation: Coyote Hills Urban Runoff Treatment Marsh, by G. Silverman, December 2, 1982.

The development sequence of a 55-acre freshwater marsh creation is reviewed including descriptions and discussions of urban drainage area, water supply, water quality, system hydraulics, marsh operation, environmental review and permit procedure, planning design and construction costs, sponsors and funding.

SAN FRANCISCO BAY AREA
REGIONAL WETLANDS PLAN
FOR URBAN RUNOFF TREATMENT

VOLUME II
TECHNICAL MATERIALS

April 1983

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WATER QUALITY MANAGEMENT PLAN

LIST OF TECHNICAL MATERIALS

WQMP/TECHNICAL MEMORANDA

- Technical Memorandum 69 - "Wetlands and Pollutant Treatment Mechanisms," by T. A. Bursztynsky, September 1981

- Technical Memorandum 77 - "Wetlands Treatment Case Studies," by E. Silveira and E. Chan, November 1981

- Technical Memorandum 88 - "Legislative Requirements and Policies in the San Francisco Bay Area," by G. Silverman, December 1982

- Technical Memorandum 89 - "Policies and Opportunities for Local and Regional Involvement in the San Francisco Bay Area," by G. Silverman, December 1982

- Technical Memorandum 90 - "Inventory of Potential Sites for the Creation of Urban Runoff Treatment Systems," by E. Chan, December 1982

- Technical Memorandum 91 - "Funding Mechanisms and Potential Funding Sources in the San Francisco Bay Area," by G. Silverman and E. Chan, December 1982

- Technical Memorandum 92 - "Case Study of Marsh Planning, Design and Creation: Hayward Shoreline Marsh - Phase II," by E. Chan, December 1982

- Technical Memorandum 93 - "Case Study of Marsh Planning, Design and Creation: Coyote Hills Demonstration Urban Stormwater Treatment (DUST) Marsh," by G. Silverman, December 1982

W.Q. Tech. Memo No. 69
Terry A. Bursztynsky

REGIONAL WETLANDS PLAN
FOR URBAN RUNOFF TREATMENT

WETLANDS AND POLLUTANT TREATMENT MECHANISMS

Technical Memorandum No. 69
September 1981

INTRODUCTION

This memorandum is the first in a series which will develop design concepts and a master plan for the use of wetlands to treat urban runoff pollutants in the Bay Area. The subjects of this memorandum are the types of wetlands and physical, chemical and biological pollutant removal mechanisms. Subsequent memoranda will review Bay Area and national case studies or reports on specific wetlands. Much of the material presented here is extracted from an ABAG study report prepared for EPA and entitled "The Use of Wetlands for Water Pollution Control." This report, which is not yet ready for publication, is being supplemented by Bay Area specific information and case studies.

TYPES OF WETLANDS

Wetland Characteristics

The term "wetlands" is a relatively new designation for marshes, bogs, swamps and other low-lying land dominated by saturated soil conditions [1]. Numerous efforts have been made to define wetlands in terms of function and characteristics. Most definitions reflect the fundamental role of water and hydrogeological factors in wetlands [2]. Cowardin et al. [1] have established the following definition to be used in conjunction with the ongoing national wetlands inventory.

> "Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."

o Natural Wetlands

Descriptions of the principal types of natural wetlands, according to hydrological factors, are provided in Table 1. Included are (a) riverine, (b) lacustrine, (c) palustrine, (d) brackish, and (e) tidal. The system characteristics, representative vegetation types and some of the important environmental sensitivities are also shown. In this classification system, based on Cowardin et al. [2], saline tidal wetlands are represented by the estuarine system.

Brackish marshes often occur within salt marsh areas near streams, and in many cases can be considered as a type of salt marsh. In Table 1, brackish marshes are identified as a separate category to represent marshes subject to salinity changes but not influenced by tidal actions, as in the case of salt pans and seasonal inland marshes.

o **Artificial Wetlands**

Artificial wetlands are the result of establishing wetland vegetation and the required hydrologic conditions in locations where they previously did not exist. Examples might include the creation of ponds and marshes for wildlife and aquatic habitat enhancement. Lowlands converted for use as permanent stormwater retention basins are another possibility. Trenches and ponds constructed specifically for physical and biological treatment of wastewaters may also take on the form of artificial wetlands. In many such cases, the substrate and vegetation established are foreign to the immediate locale. Table 2 provides a listing of some of the principal types of artificial wetlands encountered in this study.

All of these systems exhibit some of the basic ecologic features presented earlier in Table 1 under natural wetland systems. Artificial marsh systems function in a similar manner to riverine systems where there is ample circulation, an abundance of wetland vegetation, and maximum interaction between water, vegetation and sediments.

Pond systems function similarly to a freshwater lacustrine system. The type of treatment depends on the design of the basin. Deep basins without cultivated vegetation function as simple wastewater treatment lagoons where sedimentation, algal growth and adsorption to particles occur. With aeration, growth of microorganisms is promoted and breakdown of some organic material occurs. The same processes occur to a lesser degree without aeration, due to the presence of different types of microorganisms. With the growth of submerged and floating plants such as duckweed and water hyacinth, contaminants can be absorbed through plant metabolism. Primary productivity and sedimentation can occur at a high rate in these systems, which leads to pollutant sinks forming in the vegetation and sediments. Since the water level in these systems can be controlled, the vegetation can be skimmed from the surface and harvested, and the bottom deposits can be scraped or dredged out.

TABLE 1. CLASSIFICATION OF NATURAL WETLAND SYSTEMS[a]

Wetland system	System characteristics	Vegetation types	Sensitivities
Freshwater Marshes - Riverine (associated with water channels)	Water circulation distributes dissolved and suspended materials through system. Good aeration and light penetration.	Emergent plants - cattails, reeds, sedges, bulrush, watercress; floating algae.	Subject to sedimentation, scouring and seasonally-changing water levels. Pollutant loadings vary with watershed.
Freshwater Marshes - Lacustrine (associated with ponds and lakes)	Temperature/oxygen stratification and light attenuation can cause major differencees in top, middle and bottom layers. Circulation is often poor.	Floating plants - duckweed, water fern, water primrose, pondweeds and others. Emergent plants - see riverine system; submerged plants.	Closed or semi-closed systems. Pollutants enter food chain or accumulate in sediments.
Freshwater Marshes - Palustrine (not confined by channels or adjacent to lakes)	Surface layer has thick and/or porous deposits with high organic content. Marsh is fed by subsurface seepage/high groundwater.	Peat bogs, cypress, mangrove and papyrus swamps - vegetation types often-specific to geographical area.	Isolation from open water bodies (streams, rivers and lakes) limits water exchange, forming potential pollutant sink.
Brackish Marshes - (salinity > 0.4 ppt)	Marsh fed by seasonal surface flows and/or seepage; may also be subject to tidal influences; can experience salinity fluctuations.	Emergent plants - sedges, bulrush, pickleweed, saltgrass, saltbush.	Evaporation can lead to salinities of 60-80 ppt and concentration of pollutants.
Salt Marshes - (subject to tidal influence)	(1) wetlands near streams (2) lower wetlands - reversing flow (3) lower wetlands - drained only at low tides (4) upper wetlands - inundated only at high tides	Emergent plants - pickleweed, cordgrass, sedges, saltgrass.	Salinity and sediment interactions can trap pollutants; however, low pH and oxidizing muds can re-release pollutants to system on a continuing basis.

a. Derived from references 2, 3 and 4.

TABLE 2. ARTIFICIAL WETLANDS USED FOR THE TREATMENT OF WASTEWATER OR STORMWATER[a]

Type	Description
Marsh	Areas with impervious to semi-pervious bottoms planted with various wetlands plants such as reeds or rushes.
Marsh-pond	Marsh wetlands followed by pond.
Pond	Ponds with semi-pervious bottoms with embankments to contain or channel the applied water. Often, emergent wetland plants will be planted in clumps or mounds to form small subecosystems.
Seepage wetlands	Wastewater irrigated fields overgrown with volunteer emergent wetland vegetation as a result of intermittent ponding and seepage of wastewater.
Trench	Trenches or ditches planted with reeds or rushes. In some cases, the trenches have been filled with peat.
Trench (lined)	Trenches lined with an impervious membrane usually filled with gravel or sand and planted with reeds.

a. Derived in part from reference 2.

Seepage wetlands, and lined and unlined trenches fall roughly in the category of palustrine systems. Water applied to these systems generally does not exit as surface runoff but infiltrates through the wetland layers to the groundwater or to underdrains. Vegetation may aid in the treatment process, but the most critical factor is the use of soils with high permeability rates, such as gravelly soils and alluvial deposits. The success of an infiltration system often depends on alternate wet and dry cycles to allow for proper soil reaeration. In this sense, it probably does not function as a true wetland system and can best be described as a hybrid wetland-dryland system.

WETLAND SYSTEMS FOR WASTEWATER TREATMENT

The planned utilization of wetland systems for treatment of municipal wastewaters is a relatively recent innovation. Nonetheless, most of the available information on wetland response to pollutants comes from this type of application.

Natural Wetland Treatment of Wastewater

In most cases to date, the primary objective has been to provide a tertiary level of treatment, mainly to meet nutrient removal requirements. Discharge of secondary effluent to wetlands seeks to take advantage of natural treatment processes related to four principal features of wetlands [1]:

(1) Dispersion of surface water over a large area through intricate channelization of flow;

(2) Utilization and transformation of elements by microorganisms;

(3) Physical entrapment through sorption in the surface soils and organic litter;

(4) Uptake and metabolic utilization by plants.

Experimentation with wastewater discharges to natural wetlands has occurred in many different parts of the U.S. and Canada. Examples of wetlands that have been examined for wastewater treatment include the following:

- o cypress domes (Florida) [5, 6, 7];
- o northern peatlands (Michigan, Wisconsin) [8, 9];
- o cattail marshes (Wisconsin) [10, 11, 12];
- o freshwater/tidal marsh (New Jersey) [13, 14];
- o lacustrine marsh (Canada) [15];
- o swamplands (Canada) [16];
- o southern freshwater marshes (Florida) [17, 18, 19].

As is evident from this listing, a range of different types of wetlands are under investigation. Some of the wetland systems have been receiving wastewater discharges for long periods of time while others are the subject of recently initiated pilot studies.

Artificial Wetland Treatment of Wastewater

The use of artificial wetlands for wastewater treatment seeks to take advantage of many of the same principles that apply in natural biological systems, but to do so within a more controlled environment. Small-scale wetlands have been created expressly for the purpose of providing wastewater treatment [20, 21, 22], while others on a larger scale have been implemented with multi-use objectives in mind, i.e., using treated sewage effluent as a freshwater source for the creation and restoration of marshes for environmental enhancement [23, 24].

The use of artificial wetlands for wastewater treatment is founded largely on the work of Kathe Seidel and her co-workers at the Max Planck Institute in Germany [20]. Since the early 1950's, they have been studying the wastewater treatment capabilities of plants established on artificial substrates. More recent developments have included the use of peat filters, floating plants (e.g., duckweed and water hyacinth), and large-scale creation of wetland habitat. Artificial wetlands have been studied for their capabilities to provide primary and secondary wastewater treatment as well as for advanced or tertiary treatment. They afford much greater operational flexibility than do natural systems. Some systems are set up to recycle a portion of the wasteflow and to direct the final effluent into the soil for recharge purposes [22]. Others act as flow-through systems, discharging final effluent to receiving waters [23, 24].

Examples of typical artificial wetland systems used for wastewater treatment include the following:

- o meadow-marsh-pond system (New York) [22];
- o ponds with reeds or rushes (Germany, Holland) [20, 21];
- o peat-filled trench systems (Finland) [25];
- o peat filter (Minnesota) [26];
- o marsh-pond system (California) [23];
- o seepage wetland (Michigan) [24];
- o hyacinth pond systems (Texas, Florida) [27, 28, 29].

These examples show a wide geographical distribution and active interest in a range of wetland vegetative systems. There are currently many in the field promoting expanded utilization of artificial, rather than natural, wetland systems [10, 30].

WETLAND SYSTEMS FOR STORMWATER TREATMENT

The primary objective of stormwater management is to minimize inconvenience, hazards and damage resulting from the accumulation of stormwater runoff. The conventional approach has been to provide a system of channels and pipes to carry away rainfall as quickly and efficiently as possible [31].

Wetlands Treatment of Stormwater

Many wetlands have been receiving inadvertent discharges of stormwaters for a number of years. To date, there have been only a few instances where stormwaters have been specifically routed into natural or artificially-created wetlands for flood control or water quality management purposes. Where the practice has been employed, consistent reduction of BOD, suspended solids and heavy metals generally have been shown. Stormwater treatment through wetlands encompasses three categories:

(1) Systems planned primarily for flood control with treatment as an incidental benefit;

(2) Systems planned and operated with treatment of stormwater pollutants as a primary objective;

(3) Existing wetland systems providing detention and treatment of stormwater flows as an unplanned, natural function.

The factors responsible for wetlands treatment of surface runoff are largely the same as those noted previously in reference to wastewater treatment. In principle, wetlands offer hydraulic resistance to surface runoff flowing through them, resulting in decreased velocities and increased deposition of suspended sediments. The large surface area provided by surface soils and vegetation contributes to higher levels of physical absorption, adsorption, microbial transformation and biological utilization than normally occurs in more channelized water courses [9].

The utilization or creation of wetlands for stormwater treatment is limited by several factors, including:

(1) Proximity of natural wetlands to sources of runoff needing treatment;

(2) Seasonal and sporadic nature of stormwater runoff where reliable water supply is needed for maintenance of wetland vegetation;

(3) High flows and flushing action associated with runoff events;

(4) Potential for creating nuisance vector and odor problems.

A variety of management practices have been suggested to overcome these limitations and enhance the overall capabilities of wetlands for treatment of stormwater runoff. Detailed discussion of possible measures, including techniques related to inflow/outflow regulation, water level manipulation and flow distribution, will be provided in subsequent technical memoranda.

Examples of instances where wetlands have been employed, examined or proposed for treatment of stormwater include:

- o northern peatlands (Minnesota) [32];
- o cypress wetlands (Florida) [33];
- o brackish marsh (California) [34];
- o high altitude meadows (California) [35];
- o vegetated retention basins (Maryland) [36];
- o southern freshwater marsh (Florida) [37].

o Detention/Retention Storage Basins

The use of landscaped basins for the detention or retention of surface runoff has become a popular stormwater management technique throughout the U.S. during the past 10 years. Such facilities may take the form of either onsite or offsite impoundments where runoff is collected for (a) controlled downstream release (detention), or (b) containment and infiltration (retention), or a combination thereof. The design of such facilities will vary depending upon the land costs, space availability, physical and aesthetic characteristics of the area, topography, climate and other local factors [38]. Whether or not the detention/retention facility is to serve multipurpose uses, such as runoff treatment/disposal and recreation, is a factor that may dictate size, shape, depth and landscaping.

Detention/retention storage basins may provide for surface runoff pollution control in a variety of ways [39]:

(1) Infiltration and entrapment of pollutants in the soil;

(2) Flow detention and velocity reduction which minimizes erosive forces in downstream areas;

(3) Delaying and evening of runoff pulses and consequent shock loading of pollutants to receiving waters;

(4) By reducing flooding, reduction of surface water flow across urban street surfaces where large quantities of pollutants may be picked up and transported by runoff;

(5) Reduction of stormwater pollutant loadings, through the settling of particulate matter and biological oxidation of organic materials in ponding areas.

Vegetation at detention/retention facilities primarily is planted for aesthetic reasons; however, other specific purposes might include [38]:

- o recreational needs (i.e., turfed ballfields);
- o improved infiltration;
- o erosion control;
- o barriers to auto and pedestrian access.

The planned use of vegetation for uptake or reduction of surface runoff pollutants in these facilities has gained little attention to date.

PHYSICAL AND CHEMICAL POLLUTANT REMOVAL MECHANISMS IN WETLANDS

A description of pollutant removal mechanisms that may operate in a marsh excludes few aquatic processes that can be found in any natural water body. All the mechanisms that are discussed in this section are not important in every marsh. Indeed, some are mutually exclusive, occur only seasonally, or are of secondary importance at most sites. However, most of these mechanisms are likely to occur to some degree in the majority of marshes.

This section describes pollutant removal processes that occur in natural waters and are likely to apply to marshes. Many have not been documented in marsh environments, largely due to the traditional neglect marsh research has received as compared with studies of rivers, lakes and oceans. Nevertheless, processes are discussed as long as they are likely to occur in some marshes to some degree.

Pollutant Mass Balance

Pollutants may enter a marsh via surface runoff or point source discharges. Other routes, e.g., through base flow, aerial fallout, and mobilized solid waste deposits, are not addressed here although the same treatment processes would be operative.

Surface runoff pollutants entering a marsh occur on the surface or in the water column, either dissolved, emulsified, or in particulate form. Likewise, surface water flowing from a marsh carries pollutants in the same ways. These substances are not necessarily the same as the inflow pollutants. Many types of transformations occur in marshes and the products may leave the marsh. Pollutants can be removed by a wetland system through three main routes: loss to the atmosphere, incorporation into sediments or biota, and degradation. Some products of pollutant degradation may be inert or nontoxic, while others continue to pose environmental hazards. For example, some readily oxidizable organic compounds are quickly converted to carbon dioxide and water. On the other hand, some pesticides are very stable or yield stable degradation products which are also toxic to the environment. Regardless of the nature of the products of pollutant transformations, they either flow out of the marsh, volatilize, or remain in the marsh, fixed in biota or sediments. A summary of the major pollutant removal mechanisms and the contaminants affected is presented in Table 3.

Pollutant Loss To Atmosphere

Generally, the atmosphere acts as a sink rather than a source of pollutants to marshes. In some cases, however, aerial input may be an important factor, such as for lead in auto exhaust [40], solids from wind erosion of soil, and acid rain. Loss of pollutants to the atmosphere occurs by evaporation [41] and by aerosol formation [42]. Evaporation is by far the more significant of the two mechanisms for most marsh environments.

TABLE 3. PHYSICAL AND CHEMICAL POLLUTANT REMOVAL MECHANISMS IN WETLAND AND AQUATIC SYSTEMS

Mechanism	Pollutant affected									Description
	Settleable solids	Colloidal solids	Organic compounds	Petroleum hydrocarbons	Nitrogen	Phosphorus	Heavy metals	Bacteria and viruses	Halogenated hydrocarbons	
Physical										
Evaporation			X	X			X[a]		X	Volatilization and aerosol formation
Sedimentation	X	X		X	X		X[b]		X	Gravitational settling of particles and adsorbed pollutants
Emulsification		X	X	X			X[a]		X	Suspension of chemicals that are sparingly soluble in water within an aqueous environment
Adsorption		X						X		Electrostatic attraction, Van der Waals force
Filtration	X	X						X		Mechanical filtration of particles through substrate, roots or animal systems
Chemical										
Chelation						X	X			Formation of metal complexes through ligands
Precipitation				X		X	X			Formation of or coprecipitation of insoluble compounds
Decomposition			X	X	X	X	X	X	X	Alteration of less stable compounds by oxidation, reduction, hydrolysis or photochemical reaction
Chemical adsorption			X	X	X	X	X		X	Covalent bonding, hydrogen bond formation, hydrophobic interaction

a. Significant only for mercury.
b. Not significant for manganese and mercury.

The presence of a surface film can decrease the rate of volatilization by acting as a barrier to volatile solutes in the water which are insoluble in the film. Alternatively, the surface film can scavenge substances from the bulk water and concentrate them at the surface where they subsequently are volatilized. Surface films occur in both freshwater and marine environments. They are composed of a highly variable array of compounds including fatty acids, esters, alcohols, lipids, hydrocarbons and proteinaceous materials. Surface films can contain dead fish, insects, and various living organisms and can be richer than the subsurface water in phosphorus, nitrogen, carbon, most heavy metals, chlorinated hydrocarbons and other materials [41, 43]. Concentrations of zinc, cadmium, lead and copper may reach 100 ppm in surface films, promoting reactions that may not otherwise occur and allowing ready entrance for the metals to the food web through surface feeding fish, insects and other organisms.

Environmentally important pollutants for which volatilization may be a significant fate include oils [44, 45, 46], chlorinated hydrocarbons [42], 2,4-D esters [47], and elemental mercury [48]. The multitude of compounds making up petroleum oils vary greatly in their volatility. The acutely toxic, low-boiling-point alkanes evaporate quickly while the atmospheric loss of most large molecular weight petroleum hydrocarbons is negligible.

Sedimentation

Sedimentation is one of the most important mechanisms by which particulate pollutants are removed from the water column. Particulate matter may be considered a pollutant, either because it consists wholly of pollutant material or because pollutants are adsorbed to the surface of naturally occurring particles.

In natural waters, particulate matter usually occurs as a mineral in an organic matrix [48, 49, 50, 51]. For example, the inorganic portion may be clays, quartz particles or hydrous metal oxides while the organic part is usually humic or fulvic acids. The clay particles in fresh waters usually have negative charges. Ions in the water surround negatively-charged particles, forming an electrically neutral "double layer." Repulsion between like charges prevents the particles from agglomerating into larger, more readily settling solids. The degree and rate of agglomeration of particles depends upon the frequency of collisions between particles in the water and the efficiency of the collisions. Dissolved ions that do not interact with the colloidal particle can increase collision efficiency by compressing the diffuse part of the electric double layer with counter ions, allowing Van der Waals forces to cause agglomeration. An example of this is the enhanced settling of suspended matter in estuaries [50]. In freshwater the collision efficiency is only 0.0001 to 0.000001, but in sea water it rises to 0.1 to 1.0. Thus, sediment-laden freshwater flows entering an estuarine system should undergo enhanced solids deposition as compared with an otherwise completely freshwater system [52].

Quiescent bodies of water, such as marshes and other wetlands, often provide long detention times. Collision frequencies caused by Brownian motion for very small particles are very low, but with long detention times there are sufficient contact opportunities for significant agglomeration and settling of finely divided solids.

Wetlands generally act as detention and regulating areas for streamflows, with beneficial effects on downstream soil erosion. Within the wetland itself, however, high flow rates associated with storm episodes, seasonal runoff or regulated discharges may resuspend previously deposited and decomposing organic matter and wash it out of the wetland system [53, 54, 55].

Sedimentation of pollutant particulates or pollutants adhering to the surface of particles can be the primary mechanism for removal of these substances from the water column. This process has been reported as important for removal of particulate nitrogen [56], oils [57], chlorinated hydrocarbons [49, 58], and metals, except for manganese and nickel [50, 59]. The chemical character of marsh water and the nature of the solid determine the extent of pollutant adsorption on the surface of suspended solids. Since the water chemistry can vary widely among marshes, an important mechanism at one location may be secondary at another.

Emulsification

Emulsions are colloids consisting of globules or particles of one liquid finely dispersed in another. They are inherently unstable and tend to coalesce unless an emulsifying agent is present to lower the interfacial energy between the two immiscible liquids. In natural systems, the most common occurrence is minute droplets of oil in water [44, 46]. The stabilizing agent is a soap, detergent, or naturally occurring organic molecule, one end of which is polar and the other nonpolar.

There are three principal mechanisms that destabilize emulsions in natural waters [60].

(1) A change in the chemical character of the water, i.e., temperature, pH, ionic strength or presence of certain solutes, may reduce the ability of the agent to stabilize the emulsion. Salinity increases, as would occur when freshwater enters a salt marsh, aid the coalescence of the emulsion colloids into larger drops.

(2) An increase in the concentration of oil decreases the emulsion stability. This could occur when a marsh volume is reduced by evaporation, thereby lowering the water-to-oil ratio.

(3) Freezing and thawing of an emulsion usually causes it to break-up [60].

Emulsion colloids are important to the fate of pollutants in wetlands because, aside from containing toxic oils, they tend to accumulate environmentally significant chemicals that are sparsely soluble in water. This is important for pollutants such as mercury, polychlorinated biphenyls (PCB's), and some pesticides [48].

Adsorption

Principal removal of dissolved pollutants by adsorption in natural waters is by adhesion to particles of suspended solids or bottom sediments. The solutes are bound to the solid phase by four main mechanisms [61, 62]:

(1) Electrostatic attraction or repulsion;
(2) Hydrogen bond formation;
(3) Van der Waals interaction;
(4) Hydrophobic interaction between the solute and water.

Extensive contact between wastewater flows and wetland soils allows these interactions to occur. The most effective results are attained in seepage wetlands where a large percentage of the flow passes through the soil complex prior to entering ground waters or discharging from the wetland [54]. In wetlands having poor soil permeability, such as peatlands, shallow water depths and long residence times promote greater contact with surface soils and increased pollutant removal efficiencies [63].

Hickok and others have found the need to promote maximum interaction of runoff and wastewaters with mineral soils for attainment of high levels of phosphorus removal in wetlands [64, 65]. In addition to low water depths, even distribution of water, such as sheet flow, enhances soil-water contact over larger effective areas of the wetland [66].

Seepage wetlands function similarly to overland flow systems, with nearly complete phosphorus removal through soil processes [54]. In such systems, unusually high runoff flows may pose problems by causing overflows and bypassing of seepage routes. Similarly, in flow-through wetlands, high runoff events reduce opportunity for soil contact and, as noted earlier, may be detrimental by washing sediments, organic matter and other constituents from the confines of the wetland.

A great number of substances adsorb to solids under conditions that may be found in wetlands. This phenomenon is well-documented in the literature:

- o organic compounds in general [48, 67];
- o petroleum and other hydrocarbons [57, 44, 68, 62, 56, 69];
- o halogenated hydrocarbons [70, 42, 71, 72, 48, 47];
- o ammonium [73, 74];
- o phosphorus [75, 76, 77, 78];
- o heavy metals [40, 50, 79, 80, 81, 51, 82, 83, 84, 59, 85, 48, 86];
- o bacteria and viruses [48, 87).

Chelation

Chelation is the process by which metals are strongly bound in a complex with anionic molecules, either inorganic or organic. The anionic part of the complex is called the ligand. There are many sources of ligands in wetland environments. Salt waters are rich in important inorganic ligands, including chloride, sulfate and bicarbonate, which can form soluble complexes with trace metals. This chelation mechanism competes with adsorption of the metals onto the surfaces of iron and manganese hydrous oxides [59].

Organic ligands are also very common in natural waters. Partial decomposition of organic matter produces a variety of low molecular weight acids which chelate metals, including amino, butyric, citric, formic, 2-keto-gluconic, malic, oxalic, tartaric, and a variety of lichen acids [51]. In addition to forming complexes, these acids lower the pH. This promotes the dissolution of metals from solids, making them available for chelation. Large molecular weight organic compounds that are found naturally also are important ligands. Primarily these are humic and fulvic acids [51, 85].

There are ligands in most wastewaters and stormwaters. Some are present specifically because of their metal binding properties. A good example of this is iron fertilizer. Ethylenediaminetetraacetic acid (EDTA) is present in fertilizer to permit uptake of the nutrient by plants [88]. Through runoff transport, EDTA and other ligands can affect distribution of metals in wetlands and uptake by vegetation.

Chelation is important to the mobility of aluminum, cadmium, calcium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc. In addition, chelation can affect the release of phosphate. As organic acids react with aluminum, calcium, iron and manganese, phosphate adsorbed to the former hydrous oxides is liberated [75].

Precipitation and Dissolution

Metals dissolve or precipitate in response to the changing aquatic environment. In anaerobic waters, insoluble ferric iron is converted to ferrous iron, which readily dissolves. In the presence of sulfide, which is common in anaerobic sediments, ferrous iron is precipitated as iron sulfide [89, 90]. Other metals, including cadmium, copper, lead, mercury, silver and zinc, form insoluble sulfides under reducing conditions common in wetlands [80, 81, 91]. In aerobic environments, aluminum, cadmium, chromium, iron, manganese and zinc form oxides and hydroxides [80, 81, 91, 78]. Dissolution of minerals that are more soluble at low pH often occurs in organic-rich sediments when acids are released by partial degradation of organic matter [51]. This process is a common cause of phosphate release [92, 75].

Oxidation and Reduction

Oxidation and reduction always occur simultaneously. Oxidation is the loss of electrons and reduction is the gain of electrons. Metals are common catalysts for oxidation-reduction reactions, but more frequently enzymes associated with microorganisms catalyze transformations of this type. For some organic compounds oxidation reduction reactions are initiated by exposure to light (in wetland environments, sunlight). In some cases, water must be included to effect a balance, but this occurs naturally in aqueous solutions.

o Oxidation

Oxidation can occur in either the presence or absence of oxygen. Autooxidation is the reaction of oxidizable material with molecular oxygen. An example important to wetlands is the oxidation of hydrogen sulfide to sulfates. This reaction is catalyzed in both fresh and salt waters by metals such as cobalt, copper, iron, manganese and nickel [93]. Oxidation of organic matter is constantly taking place in all wetland systems. The most important route is by biological mediation. When oxygen is present, the degradation can proceed completely so that carbon dioxide and water are the products. Some naturally occurring organic matter resist complete oxidation and refractory substances remain. An important mechanism for the release of metals to water is the oxidation of the organic portion of particulate matter having associated trace metals.

In wetland sediments having high content of organic matter, molecular oxygen is usually not present. Microbes can use nitrate and sulfate oxygen in these circumstances to oxidize organic matter. Theoretically, saturated petroleum hydrocarbons having as many as nine carbon atoms can be oxidized to carbon dioxide and water. Hydrocarbons with more than nine carbons can be anaerobically degraded only as far as cycloparaffins [94]. In general, readily biodegradable organic matter is anaerobically oxidized through a series of microbial transformations so that methane and carbon dioxide are the final products [95].

Other compounds are commonly oxidized in wetlands. Organic nitrogen is sequentially oxidized by bacteria in aerobic environments to ammonia, nitrite and nitrate [96]. Iron sulfide and pyrite are oxidized biologically to elemental sulfur, thiosulfate, polythiosulfate, sulfite, and sulfate [95, 90]. Arsenite is oxidized by microorganisms to arsenate [97]. Soluble ferrous ions, which diffuse into aerobic zones from underlying sediments, are oxidized to ferric oxides and hydroxides [77, 59] and chromium (III), which is common in rocks, is slowly oxidized to chromium (VI) [50]. Other metals are similarly oxidized [59].

o Reduction

Several compounds are reduced in anoxic environments to provide oxygen for the oxidation of organic matter. Usually either nitrate or sulfate is the oxygen-rich agent that is reduced. Nitrate is reduced to nitrite, then to gaseous elemental nitrogen; sulfate is reduced to hydrogen sulfide, iron sulfide, and pyrite. Under anoxic conditions, some metals are reduced to lower oxidation states.

o Hydrolysis

One of the most important hydrolytic reactions in natural waters is the conversion between ammonia and ammonium. When the water molecule is split, the hydrogen ion unites with ammonia while the hydroxyl radical remains in solution. This tends to raise the pH and provide a more favorable environment for biological oxidation of nitrogen [96].

Hydrolysis of some organic compounds occurs in wetlands. This reaction is particularly significant for materials that may be toxic to microorganisms. Hydrolysis may be a mechanism for removal of chlorinated alkanes from waters although the process may take months [42]. Metals are sometimes necessary to catalyze hydrolysis. For example, cobalt and copper can catalyze the hydrolysis of glycine methyl ester [93]. A few other illustrations of the hydrolysis of compounds having environmental significance are:

(1) The acid-based catalyzed reactions of phthalate esters and phosphate esters to yield organic acids and alcohols, which are biodegradable [67];

(2) Hydrolysis of the insecticides methoxychlor and dischlorodiphenyl trichloroethane (DDT) [98];

(3) Hydrolysis of 2,4-D esters [47].

o Photochemical Reaction

There are two basic types of photochemical reactions that occur in natural water bodies [67, 99]:

(1) Direct photolysis is the absorption of light by a compound, followed by its disintegration to more reactive fragments. When one of the free radicals created is the singlet oxygen, which is a more reactive oxidizer than molecular oxygen, the process is called photochemical oxidation.

(2) Photosensitized oxidation, also called indirect or sensitized photolysis, is the oxidation by the singlet oxygen of a substance other than the originally excited compound.

The extent of photochemical reactions is a function of the solar spectral irradiance at the water surface, the transfer of the light from air to water, and transmission through the water. In wetland waters, attenuation of light by dissolved natural organics can restrict these reactions to the upper layers. Scattering of light by suspended matter is usually much less important than absorbance [99]. Because the intensity of light usually drops so precipitously in wetland waters, the surface film is where most photochemical reactions take place [45, 47].

A number of examples illustrate photochemical reactions that can participate in the removal of compounds of environmental concern:

(1) EDTA is rapidly photodegraded in both acidic and basic waters [88];

(2) Ultraviolet radiation of hydrocarbons found in No. 2 fuel oil produces relatively soluble oxygenated compounds, including reactive peroxides, phenols and carbonyl compounds [45];

(3) Photodegradation can shorten the life of unsaturated chlorinated alkanes but probably does not occur for their saturated counterparts [42];

(4) The polynuclear aromatic hydrocarbon, benzanthracene, is photodegraded in salt waters [68];

(5) Although usually slow, many pesticides undergo photodegradation including 2,4-D esters [99, 71], malathion [100], methoxychlor and DDT [99].

VEGETATIVE TREATMENT SYSTEMS

Although the initial pollutant removal mechanisms in wetlands are physical and chemical processes, plants can increase the overall capacity of a system to retain or remove pollutants through interactions with various anaerobic and aerobic soil layers, water, and air interfaces. In particular, plant root uptake of pollutants from the sediment frees more exchange sites in the sediments for further pollutant interaction and accumulation. The primary biochemical pollutant uptake and removal processes in vegetative systems are:

(1) Uptake through plant-soil interface, via belowground roots, rhizomes, holdfasts and buried shoots and leaves;

(2) Uptake through plant-water interface, via submerged roots, stems, shoots and leaves;

(3) Translocation through plant vascular system, from roots to stems, shoots, leaves and seeds during growing season;

(4) Differential pollutant uptake, such as preferential storage of trace contaminants in specific plant parts and preferential uptake/accumulation of certain trace elements;

(5) Nonspecific pollutant uptake, occurring primarily as plants absorb large quantities of nutrients from water and sediments;

(6) Uptake and immobilization by plant litter zones, where dead, but not decomposed, plant litter sequesters pollutants through chemical interactions.

Since the majority of waterborne contaminants are adsorbed onto particulate matter, sedimentation of particulates effectively scrubs the water column, and prevents dispersal of the pollutants. These organic-rich sediments are further bound in place by plant roots. The tendency for these sediment layers to become anaerobic is probably the major factor involved in the retention of various chemical species [101]. Reducing environments allow the conversion of heavy metals into relatively insoluble sulfides and promote the removal of nitrate nitrogen through denitrification.

Vegetative systems possess a variety of mechanisms for obtaining nutrients and other elements from their environments under changing conditions. Through interaction with the various soil layers, water and air interfaces, plants can increase the overall capacity of a system to retain or remove pollutants. Since the primary mechanisms for pollutant removal in a wetland system are physical and chemical interactions that cause the contaminants to settle or be drawn out of the water column into the sediments, plant uptake of pollutants, particularly from the sediments, frees more exchange sites for further pollutant interaction and accumulation. Some researchers theorize that pollutant removal in aquatic systems is due, primarily, to bacterial metabolism and physical sedimentation (102). However, even they concede that plants provide surfaces for bacterial growth, filtration and adsorption of solids, attenuation of sunlight and nutrient absorption to retard growth of algae, and uptake of heavy metals.

VEGETATIVE POLLUTANT UPTAKE PROCESSES

Pollutants in ionic form can be actively taken up by plants and accumulated in concentrations in excess of their environment. Plant cell membranes are not permeable to free ions of elements. Ions can only be transported across the cell membrane into the plasma through carriers which are active subunits of the membrane. Carriers have been hypothesized to be enzymes in that they have active sites that are specific for particular types of ions. Different carrier-transport mechanisms appear to function at normal and low temperature levels as opposed to high temperature levels [103]. Environmental conditions, such as increased light, temperature and carbohydrate energy sources, generally promote ion transport, whereas anaerobic conditions may inhibit absorption of specific ions.

Uptake through Plant-Soil Interface

Vascular plants actively absorb ions from the soil through the root systems. Rooted aquatic plants can also absorb ions through roots, rhizomes and holdfasts. Buried portions of shoots and leaves are also capable of uptake, particularly of nutrients [21]. Uptake capability is usually directly proportional to the volume of belowground roots except in some submerged and floating plant species which have poor root systems.

Upland vegetation requires an aerated soil zone around the roots for proper plant growth. The rhizosphere or immediate zone around the roots shelters aerobic, nitrifying bacteria which convert ammonia-nitrogen to nitrate-nitrogen, the form most readily taken up by plants. Wetland vegetation, on the other hand, typically grows in saturated anaerobic substrates. These conditions favor ammonification and denitrification which result in high ammonia-nitrogen and low nitrate-nitrogen levels in the sediments and waters. Wetland vegetation is typically adapted to use not only nitrate but also ammonia and ammonium as nitrogen sources.

In a wetland or aquatic environment, pollutants such as heavy metal ions can adsorb onto particulates or form complexes with inorganic phosphorus and settle down to the sediment layers. Concentrations of these pollutants are highest in the top layers of sediments and, unless they are immobilized into nonsoluble forms, provide a rich uptake source for vascular aquatic plants. The various processes immobilizing pollutants will be discussed later in this section.

Uptake through Plant-Water Interface

Most species of wetland vegetation are able to absorb some nutrients and ionic compounds from the water via shoots and leaves, although the primary uptake would still be through the roots at the plant-soil interface. Submerged plant species, particularly those which have weak or poorly-developed root systems, are capable of absorbing the bulk of their nitrogen requirements directly through the leaves [104, 105, 106]. Uptake of nutrients and other compounds is probably affected by the same factors that influence other plant physiologic processes, such as light, temperature and dissolved oxygen.

Translocation through Plant Vascular System

Movement of nutrients and other compounds from the root uptake sites through a plant vascular system can increase the capacity of a vegetative system to adsorb pollutants. The most rapid uptake usually occurs during the growing season when nutrients are translocated from the roots to the shoots and leaves. Peak uptake generally coincides with the period of peak biomass production [107, 108, 109].

With the death of emergent and aquatic vegetation in the fall (senescence), translocation from aboveground to belowground parts and winter storage of some nutrients and other compounds occurs in wetland vegetation [107, 110, 111]. At the start of the next growing season, depending on the species, nutrient levels may have decreased in the roots and rhizomes and become concentrated in the shoots, probably preparatory for the period of new growth. Thus, at the start of the growing season, the aboveground parts (the shoots) will contain the highest nutrient concentrations [107, 110, 112]. Whether these high concentrations are sustained solely from the belowground plant resources or are a result of immediate uptake is not certain. Data indicate that root uptake could be sufficient to account for these concentrations [110]. It should be noted that peak accumulation in belowground parts generally does not occur until aboveground parts have reached their peak concentrations [107].

In some fast-growing plant species such as grasses, uptake of pollutants such as heavy metals increases with increasing heavy metal concentrations in the soil and water [113, 114]. In reed canarygrass, lead is translocated from the roots to the aboveground parts. However, unlike other emergent macrophytes, translocation back to the belowground parts does not occur when the plant senesces in the fall. Instead, as the aboveground mass falls to the ground and decomposes, the accumulated pollutants and other compounds are gradually released back to the soil and water.

Differential Uptake vs. Nonspecific Uptake

Certain plants accumulate dissolved materials, including trace contaminants, that are not required for plant growth or function. This nonspecificity is a function of general nutrient uptake processes where some minerals, such as strontium and calcium, are interchangeable ions in plant metabolism. In other cases, the accumulation of heavy metals without apparent toxic effect may be due to the presence of chelating compounds which combine with the metal ions to form harmless complexes. An example is *Potamogeton pectinatus*, a lead-tolerant plant which takes up lead readily. Incorporation into the cell wall renders the lead inactive and harmless to the plant [115].

Trace contaminants can be taken up and preferentially stored in different plant parts. In pondweed (*Potamogeton* spp.), most heavy metals tend to concentrate in the roots and rhizomes, while zinc accumulates in the stems and leaves. Tolerance of a heavy metal varies for any single plant species and tolerance of one metal does not necessarily indicate tolerance for others. In general, emergent aquatic plants have lower heavy metal content than floating or submerged plants [116].

Uptake and Immobilization by the Litter Zone

As discussed previously, some species of wetland vegetation do not translocate nutrients and other compounds to the belowground parts when the stems and leaves die in the fall. The dead plant matter eventually falls to the ground or surface waters and breaks down to form an extensive litter zone in some marshes. Dead, but not decomposed, cordgrass litter in a saltwater marsh was found to be able to adsorb heavy metals directly from the water. Decomposing litter apparently releases humic acids which act as metal chelators and effectively immobilize these pollutants. Therefore, the organic litter layer in these grass stands acted as a sink accumulating more heavy metals than the living plant mass [117, 118, 119, 120].

VEGETATIVE ADAPTATION MECHANISMS

Vegetative systems, particularly wetlands, are often subjected to widely changing environmental conditions. Mechanisms for coping with salinity and temperature extremes as well as drought and water saturation conditions in the growth medium have evolved in different plant types and species. Through these mechanisms, some plants can become tolerant of pollutant inputs. Some mechanisms may be adapted to a specific pollutant or pollution condition.

Anaerobic Respiration

Wetland systems, by definition, have high water tables at or near the soil surface. These water-saturated soils promote anaerobic conditions at least during some portions of the year and give rise to specific physiological and anatomical adaptations in wetland vegetation. By contrast, in upland systems, prolonged soil saturation and the subsequent development of anaerobic conditions will eliminate most upland vegetation.

In emergent wetland vegetation, the aerenchyma tissue allows for exchange of gases between various plant parts, and is vital to root aeration under anaerobic conditions [121]. Laing [122, 123] has demonstrated that aquatic plants have the ability to respire both aerobically and anaerobically. Of the two types of metabolism, anaerobic respiration can be sustained at a higher rate and for longer periods in aquatic plants but involves a concomitant higher consumption in food material. Other investigations have indicated that the high levels of carbon dioxide which form in the rhizomes of some aquatic plants (aerobically and anaerobically) increase plant photosynthesis [124]. However, anaerobic conditions may also inhibit the absorption of certain ions by roots and other vegetative parts [125].

Specialized Plant Functions

o Root Interactions

Root aeration during the winter months may provide a buffer from toxic substances present in anaerobic substrates, such as hydrogen sulfide or iron and manganese [126]. Seidel [20] hypothesized that root excretions may deter root decay induced by bacteria and fungi, and showed that root excretions of some aquatics destroyed disease bacteria while preserving benign populations. An additional function suggested by Seidel, which has particular significance for wastewater application, is the formation of a "protective space" in the root zone allowing benign bacteria to survive during high loadings of heavy metals or other toxic elements, and to subsequently recolonize the area for continued functioning.

o Plant Adaptations

Plant environments which are subject to widely ranging or extreme salinity conditions, such as salt marshes and alkaline salt flats, often have physiological adaptations which allow them to cope with increased concentrations of salts in the water and soil. These adaptations, in some cases, may also allow the plants to tolerate dissolved contaminants to some unspecified level. Reeds (<u>Phragmites</u> spp.) inhabit areas with a wide range of salinities (0.2 to 40 ppt) [127, 128]. Structural adaptations for salinity tolerance include starch accumulation, thicker leaves [127] and production of different types of fiber [129]. The plant also produces more aboveground runners in saline than in freshwater environments, although it is not clear whether this is an avoidance or opportunistic action.

Proline accumulation has been noted in some plants growing in saline environments, including rushes (Juncus spp.). Accumulation of this amino acid may regulate plant osmotic balance with the external medium [130].

Reduction of aboveground plant parts to fleshy stems and tubercles, such as in pickleweed (Salicornia spp.), is another adaptation mechanism for dealing with increased salinities and surplus concentrations of materials within plant tissue. Pickleweed can grow in alkaline salt flats where salinities may reach 60 to 80 ppt. Studies in a brackish marsh in California [34] have shown the ability of perennial pickleweed to absorb significant quantities of heavy metals beyond soil and water concentrations. The concentrated salts are stored in the more recent plant growth "pickle" parts. At the end of the growing season, Salicornia is able to shed the distal plant parts that, by then, are highly concentrated in salts and are discolored pink or red. By this process, the plant is rid of excess accumulations which eventually recycle back into the wetland system.

o Transformation to Nontoxic Forms

Heavy metals and other trace contaminants may be taken up by plants due to the lack of complete specificity of plant absorbance mechanisms. The ability to accept substances that may be potentially toxic to plant functions suggests the existence of a plant compound or compounds which combine with the contaminant to render it nontoxic [131]. Thus, some plants may contain chelating agents that would form complexes with specific metal ions, effectively immobilizing the pollutant until the plant matter breaks down.

o Surplus Accumulation

The concept of "luxury uptake" of nutrients such as phosphorus and nitrogen has been cited in some studies where plants absorb more nutrients than are needed for plant metabolism. This tends to occur in situations where a particular dissolved substance, required for plant function, is available in higher than normal concentrations and growth conditions are optimal. A University of Michigan study [132] showed higher phosphorus concentrations and greater productivity of algae growing near a treated sewage discharge pipe, which can probably be explained by luxury uptake. Most of the surplus phosphorus, however, was apparently immobilized within the algae during growth. Release of the surplus accumulations did not occur until plant decomposition, when the algal phosphorus was converted in the sediments to inorganic phosphorus by bacterial action [133]. The action of immobilization and accumulation of superfluous substances is similar in concept to the attenuation and accumulation of toxic ions discussed previously. The mechanics and the evolution of these processes are not well understood. However, as discussed later, they do appear to be specific for selected ions, such as heavy metals, in certain plants.

REPORTED POLLUTANT UPTAKE

Nutrient Removal through Wetlands

Wetland environments present ideal conditions for nutrient cycling and removal, particularly for nitrogen. The aerated water column and aerobic upper sediment layer promote nitrification and the formation of insoluble phosphorus-metal complexes. Reducing (anaerobic) sediment conditions and the interface between the aerobic and anaerobic sediment layers promotes ammonification and denitrification.

Wetland vegetation can function as nutrient pumps taking up nitrogen, in the ammonium as well as nitrate form, and phosphorus, in the orthophosphate form. The highest observed nitrogen removal potentials were 300 to 800 kg/ha for aboveground parts of cattails and reeds and up to 1290 kg/ha for belowground parts of rushes and cordgrass. Nitrogen assimilated into wetland vegetation can be translocated back to and stored in the roots during the plant dormancy season or returned to the litter component during senescence of aboveground parts. The highest observed phosphorus removal potentials were 30 to 80 kg/ha for aboveground parts of cattails, reeds and sedges. Phosphorus assimilated into vegetation is not translocated back to the roots, and remains in the plants or plant litter. Hydrologic variables are crucial, particularly during the high runoff season, as particulate matter and organic nitrogen and phosphorus from the litter zone can be flushed. Plant uptake and storage of phosphorus is highly variable and is not a solely reliable mechanism for phosphorus removal. However, phosphorus-metal interactions can form insoluble complexes which can accumulate into long-term sediment deposits. Tables 4, 5, 6, 7, 8 and 9 present reported nutrient uptakes by various wetland plants.

Uptake and Removal of Trace Elements

Wetland systems can function as sinks for heavy metals and other trace elements either through vegetative uptake and storage or through immobilization in the sediment layers. The observed heavy metal removal potentials range from:

(1) 0.001 to 0.38 kg/ha of cadmium, with highest removals in *Potamogeton crispus* and *Salicornia pacifica*;

(2) 0.007 to 1.58 kg/ha of copper, with highest levels in *Justicia americana* and *Salicornia pacifica*;

(3) 0.13 to 103.4 kg/ha of iron, with highest levels in *Carex stricta*;

(4) 0.026 to 1.01 kg/ha of lead, with the highest levels in *Salicornia pacifica* and *Phalaris arundinacea*;

(5) 0.001 to 1.714 kg/ha of zinc with the highest levels in *Phragmites communis*, *Carex stricta* and *Scirpus lacustris*.

TABLE 4. NITROGEN REMOVAL POTENTIAL OF EMERGENT AQUATIC VEGETATION[a]

Species	Removal potential (kg/ha)			Study area and reference
	Aboveground	Belowground	Total biomass	
CATTAILS				
Typha spp.	0.76			Poland; very acid lake (134)
	5.71			Poland; acid lake (134)
T. glauca	12	207	207	New York; winter biomass in wetlands (135)
T. latifolia	220	94.50	315	Wisconsin; marsh (107)
	509			Czechoslovakia; fishpond (137)
	53.40			S. Carolina, power plant cooling pond (138)
	53-310			Wisconsin; marsh (110)
T. augustifolia	130-330			Wisconsin (110)
	245-467			Czechoslovakia; fishpond (137)
T. domingensis	97.8			S. Carolina; power plant cooling pond (138)
REEDS				
Phragmites communis	1.37			Poland: acid lake (134)
	3.34-15.98			Poland; eutrophic lake (134)
	181-409	350-640		Czechoslovakia; fishpond (136)
		830		Delaware, salt marsh, maximum biomass (139)
	8/11			Poland; lake, three months biomass - unmown/mown (140)
	137-409	354-640		Czechoslovakia; fishpond (137)
	800			Ukraine; maximum productivity in a eutrophic lake (127)
	118-347			Poland; a range of lakes (141)
RUSHES				
Juncus gerardii		940		Delaware; salt marsh, maximum biomass (139)
		680		Maine; salt marsh, maximum biomass (139)
J. roemerianus		1230		Georgia; salt marsh, maximum biomass (139)
J. effusus			100-250	S. Carolina, power plant cooling pond (142)
SEDGES				
Carex lacustris	32	40	73	New York, wetlands (135)
	11	77	88	Wisconsin, marsh (107)
C. rostrata	32	40	73	New York, wetlands (135)

(continued)

TABLE 4. (continued)

Species	Removal potential (kg/ha)			Study area and reference
	Aboveground	Belowground	Total biomass	
SEDGES (continued)				
C. lanuginosa	9	169	178	New York; wetlands (135)
Carex spp.				Michigan; wetlands (138)
Cyperus esculentus	10-26			Connecticut; lakes (105)
Scirpus fluviatilis	53	154	173	Wisconsin; marsh (107)
S. validus	128.40			S. Carolina; power plant cooling pond (138)
S. americanus				S. Carolina, power plant cooling pond (138)
GRASSES				
Phalaris arundinacea	437			Minnesota; fertilized overland flow (143)
Spartina alterniflora		1290		Delaware; marsh, maximum biomass (139)
		980		Subtropical; marsh, maximum biomass (139)
	26-177	53-112	90-289	N. Carolina; salt marsh, various fertilization rates (144)
	11-134			N. Carolina, salt marsh (145)
	18-60			Georgia, salt marsh (146)
	20-100			Georgia; salt marsh, domestic wastewater sludge applied (146)
S. patens		140		Georgia; salt marsh (139)
		270		Delaware, salt marsh (139)
		610		Maine; salt marsh (139)

a. Source: reference 131.

TABLE 5. NITROGEN REMOVAL POTENTIAL OF SUBMERGED VASCULAR PLANTS[a]

Species	Removal potential (kg/ha)		Study area and reference
	Aboveground biomass	Total biomass	
PONDWEED			
Potamogeton spp.		56.50	Minnesota; agricultural drainage ditches (147)
P. pectinatus	6		Poland; eutrophic lake, area highly polluted with domestic wastewater (148)
P. perfoliatus	6		Poland; eutrophic lake, area highly polluted with domestic wastewater (148)
P. pulcher	19.6		New Jersey; artificial ponds, 1 months growth (149)
ELODEA			
Elodea canadensis	39.8		New Jersey; artificial ponds, 1 months growth (149)
COONTAIL			
Ceratophyllum demersum		4.47	Poland; eutrophic lake (150)
	1.34-13.1		Poland; small eutrophic lake (151)
WATERMILFOIL			
Myriophyllum excalbescens		89.66	Wisconsin (152)
M. spicatum		8.5	Poland; small eutrophic lake (153)
	64.94		Wisconsin; shallow, eutrophic, hardwater lake (154)
	83.9		New Jersey; artificial ponds, 1 months growth (149)
	56.28		Wisconsin; shallow, eutrophic, hardwater lake (155)

a. Source: reference 169.

TABLE 6. NITROGEN UPTAKE RATES OF EMERGENT AQUATIC PLANTS[a]

Species	Uptake rates kg(ha)(d)	kg(ha)(y)	kg(ha)(mo)	Study area and reference
CATTAILS				
Typha latifolia	-0.9-1.6			S. Carolina; power plant cooling pond (105)
	1.4			Czechoslovakia; marsh growing season (156)
		689		Minnesota; marsh maximum aboveground productivity (143)
		2630		Temperate climate; total plant mass at maximum possible productivity (157)
T. augustifolia			5.9-129.8	England; marsh
REEDS AND RUSHES				
Phragmites communis		270 160		The Netherlands wastewater ponds aboveground/ belowground plant mass (21)
		437		The Netherlands; maximum aboveground plant mass (139)
			0.4-378	England; marsh (158)
SEDGES				
Carex lacustris	1			New York; wetlands, growing season (159)
Scirpus americanus	-0.32-0.34			S. Carolina; power plant cooling pond (159)
S. fluviatilis		208		Wisconsin; marsh (160)
S. lacustris		260 320		The Netherlands; wastewater ponds, aboveground/ belowground plant mass (21)
GRASSES				
Phalaris arundinacea		124-272		Alberta, Canada; overland flow, wastewater (161)
		109-299		W. Canada; overland flow, wastewater (162)
Spartina alterniflora		186		Louisiana; salt marsh (163)

a. Source: reference 131.

TABLE 7. PHOSPHORUS REMOVAL POTENTIAL OF EMERGENT AQUATIC VEGETATION[a]

Species	Removal potential (kg/ha)			Study area and reference
	Aboveground	Belowground	Total biomass	
CATTAILS				
Typha spp.	0.419-0.481			Poland; acid lakes (134)
T. augustifolia	7.9 5.0 4.0			Wisconsin wastewater pond, seasonal totals of biweekly/ monthly/ seasonal harvesting schemes (12)
	6-10			Wisconsin; wastewater pond, multiple harvests (162)
	31.7			N. Europe; wastewater pond (20)
	45-65			Czechoslovakia; fishpond (137)
	32-46			Wisconsin; wetlands (110)
T. glauca	2.7	39	42	New York; wetlands, winter biomass (135)
T. latifolia	43.9	28.6	42.5	Wisconsin, marsh (107)
	77			Czechoslovakia; fishpond (137)
	6.8-32			Wisconsin; wetlands (110)
	24 43			Wisconsin; wetlands, winter/ summer plant mass (110)
REEDS				
Phragmites communis	0.126			Poland; acid lake (134)
	0.39-1.16			Poland; eutrophic lakes (134)
	32-53	38-74		Czechoslovakia; fishpond (136)
	0.4			Poland; lake, 3 month growing season (140)
	14-63.5			Sweden; lake (163)
	62.7			N. Europe; wastewater pond (20)
	14-53	38-74		Czechoslovakia; fishpond (137)
	80			N. Europe; marshes, maximum productivity (127)
	10.6-26.7			Poland; marsh (141)
RUSHES				
Juncus effusus			10-30	S. Carolina; power plant cooling pond (142)
SEDGES				
Carex spp.	0.96-3.48			Michigan; wetlands (125)
Carex lacustris	5	5.5	11	New York; wetlands (135)
	2.4	19.7	22	Wisconsin; wetlands (107)

(continued)

TABLE 7. (continued)

Species	Removal potential (kg/ha)			Study area and reference
	Aboveground	Belowground	Total biomass	
SEDGES (continued)				
C. rostrata	5	5.5	11	New York; wetlands (135)
C. languinosa	1.2	37	38	New York; wetlands (135)
C. stricta			59.3	N. Europe; wastewater pond (20)
Scirpus fluviatilis	20	32	34	Wisconsin; marsh (107)
	11.3			Wisconsin; wastewater pond, total of 4 harvests (12, 162)
S. validus	35.1-38.3			Wisconsin; wastewater pond, total of 4 harvests (12, 162)
S. lacustris			67.2	N. Europe; wastewater pond (164)
GRASSES				
Phalaris arundinacea	43.71			Minnesota; marsh maximum production (143)
	33-56			Pennsylvania; overland flow, wastewater, totals of 3 harvests/season (163)
Spartina alterniflora	6			Georgia; salt marsh (165)
	1.1-14.9			N. Carolina; salt marsh (145)

a. Source: reference 131.

TABLE 8. PHOSPHORUS REMOVAL POTENTIAL OF SUBMERGED VASCULAR PLANTS[a]

Species	Removal potential (kg/ha)		Study area and reference
	Aboveground biomass	Total biomass	
PONDWEED			
Potamogeton spp.		12.9	Minnesota; agricultural drainage ditch (147)
P. natans		3.6-11.6	Sweden; small stream polluted with domestic wastewater (166)
P. pectinatus	0.6		Poland; lake, site heavily polluted with domestic wastewater (148)
P. perfoliatus	0.6		Poland; lake, site heavily polluted with domestic wastewater (148)
P. pulcher	3.5		New Jersey; artificial ponds, 1 months growth (149)
ELODEA			
Elodea canadensis		0.03-0.93	Poland; eutrophic lake (153)
	12.1		New Jersey; artificial ponds, 1 months growth (149)
COONTAIL			
Ceratophyllum demersum		0.58-0.99	Poland; eutrophic lake (153)
	0.62-6.08		Poland; eutrophic lake (151)
WATERMILFOIL			
Myriophyllum excalbescens		8.97	Wisconsin (152)
M. spicatum		0.015-0.078	Poland; eutrophic lake (153)
	12.55		Wisconsin; shallow, eutrophic, hardwater lake (167)
	2.90-17.70		Wisconsin; lake (150)
	2.20-12.30		S. Carolina; power plant cooling pond (150)
	20.3		New Jersey; artificial ponds, 1 months growth (149)
	1.13-5.06		Wisconsin; highly alkaline lake (168)
	12.99		Wisconsin; shallow, eutrophic, hardwater lake (155)

a. Source: reference 169.

TABLE 9. PHOSPHORUS UPTAKE RATES OF EMERGENT AQUATIC PLANTS[a]

Species	Uptake rates kg/(ha)(d)	kg/(ha)(y)	kg/(ha)(mo)	Study area and reference
CATTAILS				
Typha augustifolia			0.7-32.1	Temperate marsh (158)
T. latifolia	-0.03-0.19			S. Carolina; power plant cooling pond (104)
	0.08			Czechoslovakia; marsh, growing season (156)
	0.95	31		Wisconsin; marsh, growing season total biomass (110)
		74		Minnesota; maximum productivity (143)
		403		Temperate climate; maximum productivity, total biomass (157)
REEDS AND RUSHES				
Phragmites communis		35 20		Temperate climate; wastewater ponds aboveground/ belowground (21)
			0.13-19.6	England; marsh (158)
SEDGES				
Carex lacustris	0.06			New York; wetlands, growing season (159)
Scirpus americanus	-0.04-0.05			S. Carolina; power plant cooling pond (104)
S. lacustris		50 55		The Netherlands; wastewater ponds aboveground/ belowground (21)
S. fluviatilis		53.3		Wisconsin; marsh (107)
GRASSES				
Phalaris arundinacea		70.14		Temperate climate; wastewater irrigation (169)
Spartina alterniflora	0.06			Georgia; salt marsh (165)

a. Source: reference 131.

Although pollutant removal potentials for floating aquatic vegetation are not reported in kg/ha, observed uptake and concentration in water hyacinths (Eichhornia crassipes) are significant for some heavy metals, particularly cadmium, chromium, copper, lead, nickel, gold and strontium. Tables 10 through 13 summarize heavy metal uptake by plant specie.

Uptake and Removal of Other Pollutants

Other pollutants of environmental concern that may be present in wastewaters include the trace element boron, and organic compounds such as petroleum products and pesticides. The ability to accumulate these pollutants has been studied for a few plant species only and the data are generally insufficient to make comparisons of removal effectiveness between vegetation types.

- o **Boron Uptake**

Boron is absorbed in plant systems by the same mechanisms discussed for heavy metals. Primary uptake occurs through the roots, and accumulation in aboveground parts reaches a peak when maximum plant biomass is attained. Grasses (monocotyledons) have a lower boron requirement than dicotyledons, and probably have lower removal potentials for boron.

The boron removal potentials for emergent plants are all based on studies of wastewater or cooling ponds in temperate climates. Cattails and reeds have similar removal potentials of 0.030 to 0.352 kg/ha [185, 186] and 0.37 kg/ha [20], respectively. Bulrushes range from 0.011 kg/ha in a South Carolina cooling pond [185] to 0.496 kg/ha in a wastewater pond [186]. Carex stricta exhibited the highest removal potential among emergent plants of 0.582 kg/ha [20]. Boron removal potentials of 0.007 to 0.029 kg/ha were also found in various species of water lilies [187].

Boron uptake has been studied in only one floating plant, Lemna minor (duckweed). Calculated uptake rates for boron in experimental aqueous concentrations of 0.01 to 1.01 mg/l ranged from 159 to 160 mg/(g ash-free dry wt)(wk). Boron concentrations in Lemna were 4 to 70 times greater than concentrations in other submerged aquatic plants collected from the same wastewater ponds [188].

Few submerged plants have been studied for boron removal potential. The highest reported potential is 0.11 to 0.23 kg/ha for a community of pondweed, elodea and coontail, harvested from a Michigan wastewater pond [189]. Generally, submerged plants appear to have a lower boron removal potential than emergent or floating plants. Potamageton diversifolius, growing in boron-containing waters of 0.1 to 5.2 ppb, showed a concentration factor of 10 to 50 times in the plant tissues [185]. Boron removal potentials of 0.007 to 0.083 kg/ha during the growing season have been reported for coontail (Ceratophyllum demersum) [190]. Myriophyllum heterophyllum is reported to be able to attain boron concentrations 21 to 100 times natural water levels [185]. A removal potential of .007 kg/ha was reported for Myriophyllum spicatum in a Wisconsin Lake [167].

TABLE 10. HEAVY METAL REMOVAL POTENTIALS OF EMERGENT AQUATIC PLANTS (Cd, Co, Cu, Fe, Hg)[a]

Species	Removal potential (kg/ha)					Study area and reference
	Cd	Co	Cu	Fe	Hg	
CATTAILS						
Typha augustifolia		0.006	0.068	15.80		W. Europe; wastewater ponds (20)
T. latifolia		0.010	0.360			Ukraine; reservoir (164)
REEDS AND RUSHES						
Phragmites communis		0.028	0.188	41.20		W. Europe; wastewater ponds (20)
		0.004	0.350			Ukraine; reservoir (164)
SEDGES						
Carex stricta		0.020	0.152	103.40		W. Europe; wastewater pond (20)
Scirpus lacustris		0.023	0.161	26.20		W. Europe; wastewater pond (20)
GRASSES						
Phararis arundinacea	0.001-0.005					Pennsylvania; overland wastewater disposal; varied rates (113)
Spartina alterniflora				0.19-9.90		N. Carolina; salt marsh (136)
				3.84		N. Carolina; salt marsh (170)
	0.004	0.026		5.25	0.001	S. Carolina; salt marsh (119)
S. alterniflora and S. patens	0.0003-0.0050					Massachusetts; salt marsh, wastewater suldge applied at various rates to a mixed stand (101, 117)
OTHERS						
Justica americana			0.30-0.80	9.8-38		Alabama; lake (171)
Salicornia pacifica	0.08-0.38		0.42-1.58			California, brackish marsh receiving urban runoff (34)

a. Source: references 34, 131.

TABLE 11. HEAVY METAL REMOVAL POTENTIALS OF EMERGENT AQUATIC PLANTS (Mn, Mo, Ni, Pb, Zn)[a]

Species	Removal potential (kg/ha)					Study area and reference
	Mn	Mo	Ni	Pb	Zn	
CATTAILS						
Typha augustifolia	11.22	0.004	0.027		0.629	W. Europe; wastewater ponds (20)
T. latifolia	13.66				0.600	Ukraine; reservoir (164)
REEDS AND RUSHES						
Phragmites communis	7.44	0.012	0.068		1.658	W. Europe; wastewater pond (20)
	15.60		0.068		0.500	Ukraine; reservoir (164)
SEDGES						
Carex stricta	26.38	0.008	0.067		1.714	W. Europe; wastewater pond (20)
Scirpus lacustris	40.32	0.018	0.058		1.680	W. Europe, wastewater pond (20)
GRASSES						
Phalaris arundinacea				0.106-0.437		Pennsylvania; overland wastewater disposal; varied rates (113)
Spartina alterniflora	0.02-0.42					N. Carolina; salt marsh (136)
S. alterniflora				0.028-0.116		Massachusetts; salt marsh, wastewater sludge applied at various rates (172)
	0.32				0.06	N. Carolina; salt marsh (170)
	0.35					S. Carolina; salt marsh (119)
S. alterniflora S. patens					0.048-0.301	Massachusetts; salt marsh, wastewater sludge applied to a mixed stand at various rates (101, 117)
OTHERS						
Justicia americana	1.3-2.5				2.6-5.8	Alabama; lake (171)
Salicornia pacifica				0.026-1.01	0.43-0.68	California; brackish marsh receiving urban runoff (34)

a. Source: reference 103, 131.

TABLE 12. HEAVY METAL CONTENT OF FLOATING AQUATIC VEGETATION[a]

Species	Dry weight, mg/g												Comments and reference
	Al	Cd	Cr	Co	Cu	Fe	Pb	Hg	Ni	Ag	Sr	Zn	
Water hyacinth		300					3200						96 hrs. in 0.1 ppm Cd and 10 ppm Pb solutions (173)
				0.5-2.9	0.4-2.6	15-70							Plants of different sizes from natural populations (174)
		200-670							300-500				24 hrs. in 0.6-2 ppm solutions (28)
		<.001		<0.007	<0.01		0.063	<0.001	<0.05	<0.02	<0.01	0.58	2 wks. in sewage effluent; measurements made on roots only (175)
				89-568						140-650	102-544		24 hrs. in 0.6-2.4 ppm solutions. Uptake measured as difference in metal content of substrate (176)
		2-164	4-286		15-570		25-257			4-77			6 wks. in chemical waste system. Lowest concentrations in leaves and stems; highest in roots (177)
		<0.2-281											24 hrs in 0.001-0.1 ppm solutions. Lowest concentrations in plant tops; highest in roots (178)
Duckweed					3-110								Naturally-occurring population, England (179)
	468	17.4	65	19.2	101.1	13.9		5.6			679	58	Plants growing in drainage system of coal-fueled power plant, S. Carolina (180)
	1980			26	79				1840				American River, California (181)

a. Source; reference 184.

TABLE 13. HEAVY METAL REMOVAL POTENTIALS OF SUBMERGED VASCULAR PLANTS[a]

Species	Removal potential (kg/ha)							Comments and reference
	Al	Cd	Co	Cu	Fe	Mn	Zn	
PONDWEED								
Potamogeton crispus		0.001-0.114						Indiana; shallow eutrophic lake; soil Cd concentrations 0.66-44.8 ppm (182)
P. lucens			0.024	0.087		4.250	0.400	Ukraine; shallow eutrophic reservoir. (164)
P. pectinatus			0.010	0.030		2.500	0.210	Ukraine; shallow eutrophic reservoir. (164)
					0.140	0.040	0.001	Poland; eutrophic lake, site heavily polluted with domestic wastewater, reduced growth. (148)
P. perfoliatus					0.140	0.040	0.001	Poland; eutrophic lake, site heavily polluted with domestic wastewater, reduced growth. (148)
WATERMILFOIL								
Myriophyllum spicatum	0.109			0.007	0.130	0.109	0.002	Wisconsin; shallow eutrophic hardwater lake. (167)

a. Source: reference 169.

o Organic Compounds

In the process of mineralization, such as conversion of organic-nitrogen to elemental nitrogen, many synthetic organic chemicals are converted to inorganic products by microorganisms in soils and waters. The mineralization process frees carbon and releases energy for microbial biosynthsis. Detoxification is a common outcome of mineralization [11, 160].

The organic matter represented by BOD in municipal wastewater effluent and stormwater will, initially, be removed by sedimentation or stay in solution or colloidal suspension in a wetland. The settled organic material will be microbially digested on or in the bottom sediment. High organic loads to the wetland may induce anaerobic conditions in what might otherwise be aerobic sediments.

The soluble and colloidal organic matter will be metabolized by microorganisms attached to plant roots and stems, and to much lesser extent, by microorganisms free floating in the water column. Conceptually, the wetland approximates a combination of waste stabilization pond and trickling filter.

Organic material in the effluent from a wetland, barring heavy loading and partial treatment of organic pollutants, will consist, primarily of [102]:

- o extracellular organic compounds leached during the growing season;
- o organic compounds leached from decaying vegetation;
- o algae and microbes suspended in the water column.

With some chemicals, a microbial conversion quite different from mineralization takes place. Compounds are acted upon biologically in soils and waters, but no microorganisms able to use the resulting products as sources of nutrients or energy have been isolated. This process has been termed "cometabolism" or "cooxidation" and has been observed on DDT, 2,4,5,-T, aldrin, heptachlor (1-3), and many other chlorinated and nonchlorinated molecules. Cometabolism is generally a slow process because the resulting products, in themselves, do not stimulate greater bacterial growth. Alexander [191] has conducted a survey of over 35 type reactions for transformation of chemicals of environmental significance. Although the physiological basis for cometobolism is unclear, itas been hypothesized to be related to enzyme specificity, where microbial enzymes can catalyze reactions involving several different but chemically-related substrates. The microbes will utilize those products compatible with energy and nutrient needs, while the unusable by-products gradually accumulate [192]. The cometabolized products are generally nontoxic or of low toxicity although they may be subject to biomagnification through plant uptake and living systems. Some cometabolates may be toxic only to specific organisms, with rare but significant instances where the products can be highly toxic, such as the methylation of mercury by bacteria.

Petroleum products, phenols and phenol derivatives have been studied in conjunction with oil spills and urban runoff entering vegetative systems. Other organic compounds that have been studied on an intermittent basis include growth substances, herbicides and insecticides. Uptake of organic compounds by submerged plants has not been studied.

Petroleum products are not actively taken up by emergent plants. Incidences of oil spills which spread to wetland areas generally did not cause noticeable damage to the vegetation. However, the emergent vegetation is able to act as a biological filter, promoting the proper conditions for breakdown of hydrocarbons, while the hydrocarbons are actually decomposed (oxidized) by bacteria [193, 194, 195, 186, 196, 197, 198]. Plant stems and leaves provide bacterial attachment sites, and thus, increased contact/treatment areas for hydrocarbons. The presence of cattails and bulrushes has been reported to increase the hydrocarbon decomposition rate to as much as 7 times the rate measured in the absence of emergent vegetation [199, 200]. While reeds, rushes and grasses have not been studied, a similar bacterial mechanism may also be operative. In European wastewater treatment ponds, phenol uptake rates by bulrushes is 4 mg/((100 g plant)(d). Phenol derivatives included p-cresol, xylene, pyrocatechol, resorcinol, pyrogallol, pyridine and hydroquinone [200].

Reduction of phenol concentration in solution from 25 to 100 mg/l to less than 0.5 mg/l in 72 hours appeared to be related to the presence of water hyacinth [201]. However, phenol was not recovered in the plant tissue and the phenol removal or breakdown mechanism is uncertain. In another study, water hyacinth absorbed 1.30 to 2.5 mg toxaphene/plant from a 2 mg/l solution. Toxaphene, an organic insecticide, appeared to be taken up most rapidly in the first 48 hours [202].

The uptake and accumulation of growth substances such as 2:3:5-trichlorobenzoic acid (TBA), indoleacetic acid (IAA), phenoxyacetic acid and hexose have been studied on two species of duckweed: _Lemna minor_ and _Lemna gibba_ [203, 204, 205]. Temperature, pH, growth substance concentration, light and presence of chlorine affect the accumulation rates in different plant parts [206, 203, 205].

o **Uptake of Biocides**

Insecticides and herbicides are applied to aquatic systems to reduce insect vectors and nuisance plants and algae. Accumulation of these biocides in plant tissue affects considerations for the ultimate use or disposal of plant material. This can be important in the food chain where secondary consumers can concentrate these biocides and experience toxic effects. In addition to physical and chemical removal of the biocides, the plants and highly varied microbial populations of a wetland will metabolize many organic biocides.

Biocide uptake has been studied on water lilies and jointgrass. The pesticides hexachlorocyclohexane, HCCH, and DDT accummulated 10 to 12 times ambient water levels in the water lily _Nymphaea alba_ [207]. The insecticide mevinphos was absorbed at the rate of 7 ppm/d by _Nymphaea odorata_ and _Paspalum distichum_ (jointgrass) [208]. The submerged rush _Juncus repens_ had no effect on mevinphos removal.

Water hyacinth can achieve rapid removal of diphenamid, a weed control agent, through degradation and release of metabolics back into the water [209]. Applications of the herbicide copper sulfate pentahydrate over 2 mg/l inhibited water hyacinth growth and led to increased copper concentrations in the roots [210].

o Aquatic Plants

At low biocide concentrations in the aquatic medium, submerged plants appear to be able to accumulate and metabolize biocides without showing toxic effects. Uptake of organo-chlorine insecticides is dependent upon plant lipid content and contact surface area available for absorption. Submerged plants, such as pondweed allow contact with the entire plant surface. Potamogeton pectinatus accumulated DDT and HCCH at average levels of 3.80 and 0.94 mg/kg dry wt [211]. DDT uptake comparisons have also been performed on different pondweed species [212].

Removal of the pesticide pollutants dichlorbenil, diphenamid and amitrole were measured on Elodea canadensis, Potamogeton diversifolius and Myriophyllum spicatum. All plants were affected by dichlorbenil concentrations of 0.17 mg/l and took up small amounts of diphenamid. Only Elodea accumulated amitrole [213]. Myriophyllum brasiliense can degrade diphenamid to a relatively nontoxic monomethyl derivative [214]. M. brasiliense also absorbs the herbicide simazine through the roots [215].

o Bacteria and Viruses

Little information is available on the removal of pathogens in wetland systems. Bacteria and viruses are subject to sedimentation, exposure to ultraviolet radiation, and attack by chemicals. Additionally, natural predation by other organisms will occur in a wetland. Pathogens which rely on a specific host may also die off. However, reduction rates and the safety from transmission of diseases to either humans, animals or even plants have not been established.

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W/Q Tech Memo No. 77
E. Silveira/E. Chan

REGIONAL WETLANDS PLAN FOR URBAN RUNOFF TREATMENT

WETLANDS TREATMENT CASE STUDIES

Technical Memorandum No. 77
November 11, 1981

INTRODUCTION

Pollution from surface runoff is a priority problem in the Bay Area. In particular, urban areas can account for over 60% of the heavy metals loadings to Bay Area waters and are a significant source of other surface runoff contaminants such as suspended solids, coliform bacteria, organic matter (as measured by BOD), pesticides, and oil and grease. In sufficient concentrations, any of these pollutants may have deleterious effects on aquatic plants and animals in streams, lakes, estuaries and sloughs as well as causing damage to the San Francisco Bay ecosystems.

This paper deals with the use of wetlands as a water treatment system and comprises one of a series of technical memoranda for the ABAG Regional Program on Urban Runoff Treatment through Wetlands Restoration. A previous Tech. Memo* delineated the various physical, chemical and biological treatment mechanisms to be found in wetlands. The purpose of this memorandum is to briefly present Bay Area wetland treatment functions and wetland types and to discuss selected case studies of existing wetlands that have been evaluated for their treatment capabilities or potentials.

Wetlands Treatment

A simple and cost-effective method for the treatment of urban runoff pollutants is using the natural cleansing processes of a wetland system. Temporary detention of urban runoff in a wetland can allow for the removal of significant quantities of suspended solids and the pollutants adsorbed to them, as well as the scouring of pollutants from the water column through a biological purification process. These compounds are acted upon in the plant/water, plant/sediment, and aerobic-sediment / anaerobic-sediment, interfaces. Microorganisms, aquatic plants, and animals can convert and utilize some compounds for growth while translocating or storing others in inert form. Sediment interactions can trap some pollutants, particularly heavy metals, and immobilize them for long periods in the sediment layers. Treatment of water quality constituents in surface runoff is a natural function of a wetland system. These same processes are also effective for urban runoff contaminants and municipal wastewater discharges, as well.

*ABAG Water Quality Management Program - Technical Memorandum No. 69: "Wetlands and Pollutant Treatment Mechanisms," August 1981.

A wetland treatment system can be found or constructed in numerous locations within the surface water system:

- o along the banks of stream channels,
- o old stream channels and ponding areas adjacent to stream channels,
- o constructed detention areas adjacent to stream channels,
- o estuarine areas where streams enter the Bay, and
- o intertidal areas along the Bay shoreline.

Wetlands Types

Within the Bay Area, wetlands can generally be categorized into freshwater, brackish and salt marshes. These categories are defined by the salinity range of the water and support characteristic plant and animal communities adapted to these salinities. Often one type of marsh will gradually blend into another type; however, wetlands that have been diked off from normal water circulation may exhibit only a single marsh type. Historically, surface runoff has entered all three marsh types. Municipal wastewater has generally been prohibited from being discharged to marshes. A notable exception has been in San Jose and is discussed in a subsequent section. However, wastewater discharge channels themselves may spontaneously develop marshes and wastewater discharged to nearshore areas may flow back to tidal salt marshes under certain conditions.

Freshwater Marshes -- These systems are fed by surface runoff waters and/or groundwater. In the Bay Area, freshwater wetlands are typically seasonal due to the annual rainfall pattern. These marshes are most productive during the wet season (October through April) and dormant or non-existent during the dry season. A number of these wetlands are permanent where they are supplied by perennial springs, streams or groundwater seepage. Some wetlands can become permanently established where landscape irrigation (such as for parks, golf courses and gardens) provides surface runoff flows during the dry seasons.

Brackish Marshes -- These systems are often transitions from freshwater marshes to salt marshes. The salinity normally ranges from 0.4 ppt to approximately 33.0 ppt (seawater concentration). Seasonal freshwater marshes may evaporate into brackish marshes during the dry season with a concomittant shift in vegetation types. Flooding of soils with high residual salts, (such as some agricultural lands, former baylands and areas with saltwater intrusion) may also yield brackish marshes despite the freshwater source. Where these circumstances reach an extreme, salinities may reach 60 to 80 ppt and only the most tolerant plants and animals will survive.

Salt Marshes -- These systems are subject to tidal flooding and support vegetation adapted to seawater salinities. The duration and depth of their submergence are dependant upon a number of seasonal variables such as tidal range and surface runoff and factors such as local topographic and groundwater conditions. The majority of the salt marshes in the Bay Area have been diked off for flood control, agricultural or development uses. Where the land continues to have communication with tidal waters, salt marshes still exist.

BAY AREA WETLANDS CASE STUDIES

Several wetlands receiving urban runoff or treated wastewater were identified by referring to written documents or personal communication with state and local government agencies. The various wetlands identified as receiving urban runoff or treated wastewater are summarized in Table 1. The location of each wetland is shown in Figure 1. Discussion regarding the health of these wetlands was limited to those with relevant published information.

In general, these case studies indicate the following benefits of marsh protection and restoration:

- Wetlands assimulate pollutants by cleansing the suspended sediment, nitrogen, organic material and some heavy metals from the surface runoff and keeping these wastes out of the final receiving waters.

- Wetlands provide areas for recreation, visual relief, and education within a congested urban environment .

- Wetlands provide habitats for wildlife that have declined in population due to urban development.

Palo Alto Flood Basin

The Palo Alto Flood Basin is a freshwater and brackish marsh located along the bayfront of Santa Clara County in the City of Palo Alto. The marsh receives runoff from the highly-urbanized Cities of Palo Alto, Los Altos and Los Altos Hills via the Matadero, Adobe and Barron Creeks. Approximately 18% of the basin is composed of open water channels, sloughs and inlets, while the remainder is dry most of the year. Winter storm events however, can effect greater than 80% inundation of the basin for periods ranging from several hours to several days.

Tidal inflow to the marsh is restricted by flap gates; however, the gates do allow some intrusion of tidal waters. Consequently, flora and fauna of some portions of the basin are characteristic of salt marshes because of the persistent saltwater inflow, and to some extent because of residual salts in the soil.

TABLE 1. BAY AREA WETLANDS RECEIVING POLLUTANT DISCHARGES

Wetland name/location	Marsh size/ ha	Wetland type	Discharges into wetlands	Comments
Palo Alto Flood Basin San Mateo County	240	brackish/tidal marsh	urban runoff	Subject of recent urban runoff treatment study. Marsh drainage area = 13,887 acres.
N. Novato Flood Basin Marin County	80	brackish/seasonal marsh	urban runoff	Minimal water quality problems during periods of water stagnation in summer.
Ignacio Marsh Marin County	41	brackish/seasonal marsh	urban runoff	Minimal water quality problems during periods of water stagnation in summer.
Creekside Park Marsh Marin County	7	brackish/tidal marsh	urban runoff	Tidal marsh designed and restored to maximize water flushing and dispersion and to create a diverse marsh ecosystem.
Crescent Marsh Alameda County	28	brackish/tidal marsh	urban runoff	Marsh ecosystem threatened due to increasing human intervention.
Hoffman Marsh Alameda County	1.2-1.6	salt/tidal marsh	urban runoff	Severe water quality problems caused by previous industrial discharges.
Mowry Slough Alameda County	27	brackish/tidal marsh	wastewater/ urban runoff	Despite deleterious sewage spill in 1979, marine populations appear to have fully recovered.
Mountain View Marsh Contra Costa County	8	freshwater/tidal marsh	wastewater	Freshwater marsh designed and restored to maximize the effectiveness of natural treatment mechanism. Rate of wastewater discharge = 1.5 million gallons per day.
Artesian Slough Santa Clara County	70	freshwater/tidal marsh	wastewater/ urban runoff	Despite deleterious sewage spill in 1979, marine populations appear to have fully recovered.
Coyote Hills Marsh Alameda County	18	perennial freshwater marsh	urban runoff	Groundwater is pumped into marsh during summer as part of marsh restoration project. Limited runoff received by marsh = 900 acre-feet per year.

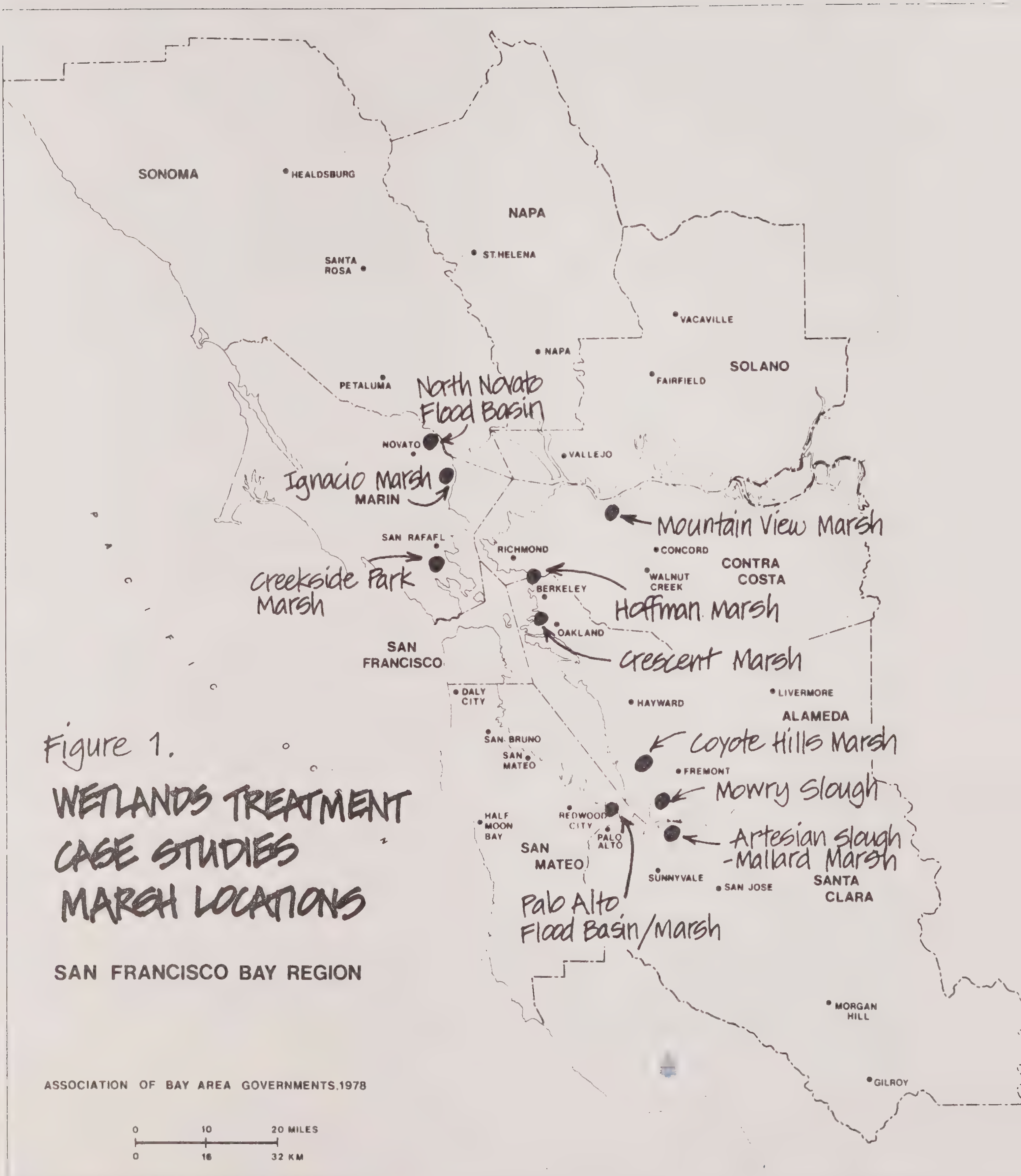

Figure 1.

WETLANDS TREATMENT CASE STUDIES MARSH LOCATIONS

SAN FRANCISCO BAY REGION

The water quality and habitat significance of the marsh has been briefly discussed in an EIR for wastewater disposal (EPA, 1978). The report describes the marsh as a "wetland and wildlife habitat of major importance." The floral components of the marsh provide permanent habitat and nesting areas for indigenous waterfowl, shorebirds and mammals. In addition, the marsh serves as wintering and resting grounds for birds of the Pacific Flyway.

The marsh was recently studied for its effectiveness in removing pollutants from urban runoff and the fate of those pollutants (Litwin, et al., 1981). The data regarding the observed pollutant removal effectiveness is given in Table 2. In general, significant removals of stormwater BOD, suspended solids, volatile suspended solids and organic nitrogen occurred in the basin. Sedimentation and filtration through the marsh vegetation caused early accumulation of pollutants in the upper portion of the basin. Concentrations of copper, cadmium, lead and zinc in flood basin plants appeared to be comparable to control areas not receiving urban runoff. Simmers, et al., (1981) reported similar findings when they compared the heavy metal concentrations in both salt water and freshwater plants from uncontaminated habitats and habitats containing dredge spoils. The heavy metal concentrations in benthic invertebrates inhabiting the site were also comparable to those occurring in pollutant-free conditions except in the case of the crustacean Corophium, which appeared to significantly bioaccumulate lead. This accumulation is not necessarily harmful to the organism since it is able to store the metal in the form of inert crystals.

North Novato Flood Basin

This fresh and brackish water wetland is located in the City of Novato, in Marin County between Highway 101 and Atherton Avenue. The wetland was diked for agricultural purposes approximately 80 years ago and thus is no longer subject to tidal influence. The wetland is seasonally flooded with urban runoff from northern Novato via Basalt and Rush Creeks. It also has a shallow groundwater source. Water from the marsh is periodically pumped out into Black John Slough by the Marin County Flood Control District.

In a recent residential development EIR (Earth Metrics, 1979), the marsh is described as a valuable brackish water habitat which supports a wide variety of flora and fauna. The marsh is particularly important to water birds; and migrating waterfowl on the Pacific Flyway depend on it for feeding, resting and possibly nesting.

Water quality information on the marsh is limited to observations of algal growth and anaerobic conditions in some marsh areas during the summer and fall. This probably implies slow circulation and shallow areas with warmer waters in some parts of the basin.

TABLE 2. OBSERVED POLLUTANT REMOVAL EFFECTIVENESS, PALO ALTO FLOOD BASIN/MARSH

Location	Wetland type	Hydraulic/ hydrologic factors	Application concentrations	Removal efficiency	Comments and reference
Palo Alto, California	Brackish tidal marsh	248 ha marsh 72 km^2 watershed 224,000 m^3 dead storage	(Average)		o Inflow/outflow pollutant relationships extremely variable from storm to storm.
(Flood control basin)		Mainly channelized flow, high marsh areas innundated infrequently.	Total N 3.67 mg/l	37%	
			Total P 0.36 mg/l	Net increase	o Outflow SS exhibited less variability than inflow levels. Because of hydraulics, very little solids deposition appeared to occur in high marsh areas.
			SS 290 mg/l	87%	
			VSS 62.9 mg/l	85%	
			BOD 12.2 mg/l	54%	o Heavy metal inflow and outflow levels were at limits of detectability.
			Cd 0.05 mg/l	NA	
			Cu < 0.01 mg/l	NA	o Pb levels consistently decreased downstream from marsh entry site.
			Ni 0.07 mg/l	NA	
			Pb 0.16 mg/l	NA	

Source: Litwin et al., 1980

Ignacio Marsh

The Ignacio Marsh is located in Marin County, directly east of the Ignacio Industrial Park in Novato. Most of the area consisted of mudflats prior to being diked for agricultural uses. The wetland is a salt marsh which receives urban runoff from the San Jose and Pacheco Creeks. Although the wetland has a seasonal source of freshwater, residual salts still occur in the soil and the downstream tidal gates occasionally malfunction - allowing bay water from Novato Creek to enter.

The hydrologic and natural resources of the wetland are described in an EIR for the Ignacio Industrial Park development (U.S. Army Corps of Engineers, 1977). During winter overflow from the two creeks, most of the 116 acres of the marsh are flooded. Approximately 26 acres consists of ponded freshwater containing freshwater marsh plants such as water plantain, water parsley, rushes and sedges. Approximately 90 acres consists of flat, disturbed areas which are intermittently flooded during the rainy season. Vegetation in these areas consists primarily of transitional marsh plants such as annual grasses, fat hen and brass buttons. Along the former Novato Creek tributary, salt marsh plants such as pickleweed, alkali heath and salt grass occur. The area serves as both a feeding and resting area for numerous wildlife species.

Discussion of the water quality of the wetland was absent except for the mention of summer stagnant water conditions, which generally infers excessive algal growth, odor and aesthetic problems.

Creekside Park-Marsh

This 16-acre marsh is part of the 27-acre Creekside Park located in Marin County on the northern side of Corte Madera Creek and Bon Air Road. The marsh was expanded in 1976 as part of a Marin Parks and Recreation development project which involved restoring to tidal action a diked land parcel adjacent to it. The objectives of the project were to (1) dredge a number of interlaced 6-to 20-ft wide waterways; (2) develop a marsh ecosystem and minimize erosion by planting and seeding a variety of marsh plants; and (3) provide public recreation and nature observation areas along the marsh perimeter. The following discussion is based on two reports submitted to Marin County (Royston, Hanamoto, Beck, and Abey, 1975 and 1976).

The marsh is under tidal influence from Corte Madera Creek and receives seasonal urban runoff from the City of Ross. The water quality and soil conditions prior to the marsh expansion project were termed "satisfactory" and both the salt marsh and freshwater marsh communities within the marsh were considered "healthy". (The parameters upon which these conclusions are based are not discussed in the reports.) The subsequent expansion of the marsh has served to dilute its unit area pollutant load, and thus may possibly have effected the improvement of the habitat qualities of the marsh.

The relatively low wildlife diversity observed in the original marsh is attributed to the small marsh size, rather than to any water quality problems. Diversity in the expanded marsh is expected to increase as a result of more open space, greater habitat diversity, and increased food supply (Newcombe and Floyd, 1976). This expectation, however, is dependent on the condition that adequate buffer zones between wildlife and humans are established.

Crescent Marsh

The Crescent Marsh, located along the bayfront of Oakland and Emeryville in Alameda County, is part of an extensive open mud flat, salt marsh and freshwater marsh. A wide frontage is exposed to tidal influence and seasonal urban runoff discharges. A few years ago, a proposal by the East Bay Regional Park District to develop recreational areas along the marsh perimeter met with great opposition from nature supporters. To understand better the potential impacts of the recreational project, the Audubon Society sponsored a study of the natural resources of the marsh and their sensitivity to human activities. The following discussion is based on this study (Bodega Bay Institute, 1978).

Cresent Marsh supports one of the richest and most diverse wildlife assemblages in the bay, due largely to the presence of freshwater marsh habitats. Freshwater inflow from Temescal Creek and urban runoff from Oakland storm drain systems have made possible the establishment of freshwater and brackish water vegetation along the southwest corridor between the Oakland storm drain discharge pipe and the narrow "neck" of the marsh. Typical plants include cattails, bulrushes, bracken fern and persicaria. A freshwater pond in the marsh supports such freshwater-dependent birds as the American bittern, the common gallinule, and a variety of duck species. The marsh also contains a salt marsh component - which supports the endangered clapper rail - and a brackish water pond.

Crescent Marsh is currently being threatened by the human activities associated the erection of "marsh sculptures" which result in trampled vegetation, destruction of nesting areas and general disruption of wildlife.

Hoffman Marsh

This tidally-influenced Alameda County marsh is located in the City of Albany bayfront, west of Hoffman Blvd., between Golden Gate Fields and the University of California Field Station. It has been the subject of several investigations relating to local industrial, solid waste and commercial development projects.

The Hoffman Marsh receives urban runoff from the storm drainage systems of Albany, El Cerrito and Richmond (Environ, 1976). Unlike the Crescent Marsh, however, the flora consist only of salt marsh species such as cordgrass and pickleweed. A few plant species generally associated with land disturbances such as mustard, fennel, wild radish, milkweed and annual grasses, are established along the periphery of the marsh.

Environ (1976) described the marsh as providing habitats for a variety of marine, aquatic, semi-aquatic and terrestrial animals, including at least two endangered species: the California brown pelican and the clapper rail. In a report by the URS Research Company (1973) the marsh was categorized as "one of the most important waterbird locations in the state." The variety of aquatic-oriented birds associated with the marsh is attributed to the calm water conditions and the number and diversity of shellfish and mud-dwelling invertebrates. The availability of detritus, diatoms and algae, contribute to the high productivity in the area.

Studies specifically relating to the water quality of the marsh are limited. One EPA study (1974) of a shellfish population in the marsh indicated that lead concentrations were in excess of FDA Alert levels; EPA suggested that contamination was a result of local industrial contamination or urban runoff.

A recent California Department of Fish and Game study of San Francisco Bay shellfish populations, which also found lead concentrations exceeding alert levels, tentatively attributed the higher levels in Hoffman Marsh to leachates originating from a large number of broken battery cases in an adjacent landfill area. The study also noted that the marsh "drains areas adjacent to the freeway where lead fallout is probably high." Thus, it appears likely that the unusually high lead levels in Hoffman Marsh shellfish are the result of these specific sources and do not necessarily reflect lead concentrations in the urban runoff from storm drains.

The overall environmental quality of the marsh has been adversely affected by historical industrial sulfur contamination. Low pH values (2.5-5.0) in the southern portion of the marsh are attributed to this contamination (Murray and Horne, 1979) and have resulted in diminished plant and animal life. Although the pH periodically drops to 4.0 in parts of the marsh, the extremely low levels are generally limited to the southern portion because of its isolation from tidal flushing. Although urban runoff cannot be completely discounted as a possible cause of adverse environmental impacts to the Hoffman Marsh, it appears that other causes have been primarily responsible for the documented impacts.

Mowry Slough

Mowry Slough is located in southern Alameda County, along the City of Fremont bayfront. It receives urban runoff from the Cities of Fremont and Newark, as well as some industrial discharges. Circulation in the slough is limited by the narrow channel size.

An EPA (1976) report concluded that based on short-term biological oxygen demand (BOD) samplings, marshes associated with Mowry Slough contributed significantly to the carbonaceous BOD of the slough. Further research on monitoring seasonal productivity and BOD inflow and outflow budgets, is necessary before the EPA conclusion can be warranted.

The wildlife components of the slough/marsh were not addressed in the EPA (1976) report. However, the area is part of the San Francisco Bay National Wildlife Refuge, and is regarded by numerous environmental groups as one of the most productive of the south bay sloughs. The U.S. Fish and Wildlife nature intrepretive center in Fremont has a number of photographs showing wildlife of the area.

Mountain View Marsh

This freshwater marsh is located in Contra Costa County near the City of Martinez bayfront. It is subject to tidal influence via a slough originating in the Carquinez Strait. Secondary-treated wastewater is discharged directly into the marsh from the Mountain View Sanitary District. The marsh was created to polish the wastewater and also as a wildlife habitat area.

Demgen (1979) published a report on the treatment efficiency of the marsh. Because of tidal flow and varying volumes of sewage discharge, the researchers found it difficult to assess the distribution of organic loads and the exact pollution reduction efficiency of the wetland. It was observed, however, that significant reductions in BOD, phosphate, ammonium and nitrate occurred within 2-5 hours as a result of the tidal excursion of the river water over the marshland. Table 3 provides a summary of the pollutant removal effectiveness of the marsh.

Although field data showed inconsistencies, probably due to the irregular flow pattern and pollution load mentioned previously, it was evident from the study that this particular marshland makes a significant water quality contribution through reduction of nutrient loads and increases in oxygen content.

Artesian Slough-Mallard Marsh

Artesian Slough is located in the City of Alviso in Santa Clara County. The marsh associated with the slough is generally referred to as the Mallard Marsh, and has historically received secondary-treated effluent from the San Jose/Santa Clara treatment plant and seasonal urban runoff.

TABLE 3. OBSERVED POLLUTANT REMOVAL EFFECTIVENESS, MOUNTAIN VIEW MARSH

Location	Wetland type	Hydraulic/ hydrologic factors	Application concentrations		Removal efficiency	Comments and reference
Martinez, California (New full-scale system)	Artificial freshwater marsh	6.1 ha wetlands plot	(Averages, 1975)			o Marsh purposely managed to enhance wildlife rather than to optimize pollutant uptake.
		63% open water	NH_3-N	7.0 mg/l	24%	
		37% emergent vegetation	NO_3-N	6.1 mg/l	56%	
		4687 m^3 capacity	NO_2-N	0.38 mg/l	Overall increase	
		4.8 days retention time at 6056 m^3/d	Total organic N	4.1 mg/l	12%	
		current retention time about 10 days	PO_4-P	10.4 mg/l	13%	o Best phosphate removal during summer months.
		current loading is 2839 m^3/d secondary-treated effluent	BOD	19 mg/l	36.8%	o High BOD readings in summer months due to algae.
			SS	22 mg/l	Not available	o Measurably lower SS values during cooler months but significant increase during summer algal blooms.

Source: Demgen and Nute 1979, Demgen 1979

According to EPA (1976) the impacts associated with discharging wastewater into the marsh were beneficial. In fact, other deep-water wastewater discharge alternatives discussed in the report were met with great opposition, in part, because of the greater positive benefits associated with the no-project alternative. Several letters were written to EPA stressing the importance of continuing the wastewater flow into the marsh, because the flow maintained a freshwater marsh. Patricia Port, a Regional Environmental officer with EPA made the following statements:

> "In general, projects that would result in improved water quality receive our support and encouragement. Occasionally, however, special circumstances come into play which complicate our evaluation. The freshwater inflow from the San Jose-Santa Clara Treatment Plant into Artesian Slough is such a case. Most of the freshwater marshes in the San Francisco Bay area have been lost because of diking, filling, channelization, intensified but short-term runoff from developed areas, and upstream reservoir storage. The few remaining freshwater wetlands are extremely important because of their scarcity and because several wildlife species depend on this type of habitat for portions of their life cycle....
>
> "We believe the freshwater marsh along Artesian Slough is important to wildlife in terms of productivity and diversity and that the removal of the freshwater source will greatly reduce, if not completely eliminate, the existing values. We believe advanced treatment methods are available and can protect the beneficial uses of the receiving water. In the event that the "basin plan" alternative (discharge north of the Dumbarton Bridge) is selected, provisions for the release of enough freshwater to Artesian Slough to maintain the freshwater marsh should be included."

Dr. Howard S. Shellhammer and Dr. H. Thomas Harvey, biology professors at San Jose State University and specialists regarding local marshes made the following comments:

> "There are few valuable freshwater or near freshwater areas left such as that at Artesian Slough near Alviso. That area supports large numbers of birds and is freshened by the outfall of the San Jose and Santa Clara Water Quality Control Plant, now an advanced secondary treatment plant. Waters from that plant may someday in the future be used also to create a new freshwater marsh in the New Chicago Marsh, a portion of the San Francisco Bay Wildlife Refuge located adjacent to their new Alviso area educational center. Wastewater cleaned to the extent that the San Jose plant now does with its nitrification and multi-stage filtration appear to be adequate for use in the creation of such a freshwater marsh."

Dr. L. Richard De Waldt, Professer Emeritus of Zoology at San Jose State University and an ornithologist stated the following:

> "In the matter of preservation of the primitive and once extensive fresh and brackish water fringe marsh lands of the South Bay and the species of plants and animals which inhabit them, we have continued to lose ground (= marsh). We now have the opportunity to reverse this trend and with careful management restore at least some of the fresh and brackish water marsh lands with the vastly improved quality of water being discharged from the San Jose Sewage Treatment Plant.
>
> "... (We can) use this reclaimed water for the restoration and wildlife resources and thus the improvement of the quality of the life of the people of the San Francisco Bay Region."

Coyote Hills Marsh

This freshwater marsh is located in Coyote Hills Regional Park in the City of Fremont in Alameda County. Approximately 45 acres have been developed as a marsh area receiving intermittent surface runoff from local areas and pumped groundwater during the dry season.

The marsh forms an integral part of the park's ecology. A variety of freshwater plant species-including some rare species - suports a wide range of terrestrial and aquatic wildlife [East Bay Regional Park District]. Roughly half of the wildlife in the 465 - acre park centers around the marsh. The area is one of the largest nesting sites of the rare tri-colored blackbird and serves also as a breeding area for the saltmarsh yellow-throated warbler-which has been proposed for Federal protection [East Bay Discharger Authority, 1979].

No water quality data are available for this marsh. Due to limitations in the upstream conveyance system, water supply to the marsh has been intermittent. The marsh is most productive during the wet season and declines during the summer and fall directly in proportion to the diminished water supply.

SOUTHERN CALIFORNIA WETLANDS CASE STUDIES

A recent research report compared the productivity of four southern California salt marshes subjected to differing degrees of tidal flow (Eilers, 1981). Table 4 gives the annual average productivity rates for these marshes. Sweetwater and Newport marsh are both subject to seasonal urban runoff discharges. After monitoring several parameters over a one year period, the researchers found that drainage and salinity have the greatest influence over floristic zonation patterns. Increased productivity was correlated with plants from the high intertidal or

maximum drainage zone. *Salicornia* was the most productive plant in the higher zones, and was also most tolerant of high salinity levels. Restricted tidal flow between Los Penasquitos and the estuary appeared to limit nutrient transport out of the marsh; thus, the coinciding increase in nutrient availability may have been responsible for the higher productivity rate observed. The effects of urban runoff on the productivity of these marshes was not assessed.

TABLE 4. SOUTHERN CALIFORNIA WETLANDS CASE STUDIES

Marsh name/ location	Size, ha	Tidal flow	Productivity rate, $g/(m^2)(y)$	Floristic diversity	Salinity range, ppt	Comments
Sweetwater River Estuary, San Diego County	23	full influence	3196	high	30-65	Urban runoff during winter season discharged into marsh.
Upper Newport Bay Orange County	58	full influence	2150	high	30-55	Urban runoff during winter season discharged into marsh. High turbidity and rapid siltation along creeks; requires periodic dredging. Dredge spoils dumped along marsh perimeter. Large avian nesting and feeding area.
Los Penasquritos Lagoon, San Diego County	95	seasonally closed from tidal inflow	3787	low	15-90	Only high marsh and upland transitional zones were discernible. Highest productivity in areas of reduced tidal contact. It was suggested that due to retarded litter loss, greater nutrients remain within the marsh rather than transported to the estuary.
Bolsa Bay, Orange County	800	permanently closed from tidal inflow	2494	low	20-40	Greater productivity along higher levels than along creeks.

Source: Eilers, 1981

CASE STUDIES OF NATIONAL WETLANDS TREATMENT OF WASTEWATER FLOWS

The use of wetlands for wastewater treatment and nutrient assimilation of point and non-point source pollutants has received considerable recent attention in other parts of the United States, as well. The past ten years have seen promising results with experimental applications of wastewater to peatlands in Michigan and Wisconsin (Kadlec, et. al., 1978; Tilton and Kadlec, 1978 and 1979; and Spangler, et al., 1976), tidal marshes in Louisiana and New Jersey (Wigham and Simpson, 1976 and Valiela, et al., 1973), cattail marshes in Wisconsin (Fetter, et al., 1978, Spangler, et al., 1976 and 1976), cypress domes in Florida (Fritz and Helle, 1979 and 1979; and Mitsch, et al., 1976), and other natural and artificially-constructed wetland systems in various regions of the country. A discussion of the experience and findings of several major investigations with different types of wetlands is presented below. A summary of observed pollutant removal efficiencies for most of the referenced studies is provided in Table 5.

Northern Freshwater Marshes

- **Vermontville, Michigan**

In Vermontville, Michigan, a seepage wetland system was constructed to provide final treatment (phosphorus removal) for pond-stabilized wastewater [Williams and Sutherland, 1979; Sutherland and Bevis, 1979; Williams, 1980]. The system is operated in a manner similar to flood irrigation, with treatment provided by nutrient uptake in upland grasses, and soil-water interaction as wastewater seeps downward and laterally from the irrigation fields. The grasses are harvested periodically. The irrigated land has become a marsh area, inhabited by a wide variety of volunteer wetland plant species, including cattail, willow, duckweed, grass and goldenrod. During the irrigation season, areas of standing water support a variety of waterfowl and other wildlife. The primary treatment objective of phosphorus removal is obtained for most of the year. The exception is in the late spring and summer irrigation season when the wetland actually increases phosphorus amounts above those of the applied wastewater. This is in part due to inputs of rainfall which cause wastewater to pass over the surface of the marsh, bypassing seepage routes. These results are in agreement with other wetland studies which suggest that the flow-through process without substantial contact and filtration by native soils might prove unsatisfactory for removal of phosphorus.

- **Brillion, Wisconsin**

Much work has been carried out in Wisconsin concerning the feasibility of using natural and artificial marshes to provide secondary and tertiary treatment of wastewaters. Investigations by Fetter et al., [1978] on a natural cattail (Typha) marsh at the city of Brillion provide some of the most informative practical experience with freshwater marshes subjected to long-standing wastewater discharges. The 15-month study showed significant improvement in wastewater and stream quality after passage through the marsh. In terms of critical

TABLE 5. OBSERVED POLLUTANT REMOVAL EFFECTIVENESS OF WETLAND-WASTEWATER TREATMENT SYSTEMS

System/location	Wetland type	Hydraulic/ hydrologic factors	Application concentration	Removal efficiency	Comments and reference
Brillon, Wisconsin (Existing discharges)	Cattail marsh (deep water)	156 ha marsh 49.7 km^2 watershed Population contributing wastewater - 2,588 Hyd. loading - $2.2x10^4$ m^3 to $4.6x10^4$ m^3 per month Ave. water depth of .5 m Hyd. residence time of 48 to 145 days	NO_3-N 1.17 mg/l Total P 3.13 mg/l BOD_5 26.9 mg/l SS 154 mg/l	51.3% 13.4% annual 80.1% 29.1%	o Decrease in NH_3-N and NO_3-N partially attributable to plant uptake. o P shows a strong seasonal fluctuation. Nutrients mobilized during periods of low biological activity (fall-winter). o BOD values consistently reduced to below background levels except in winter, when marsh iced over. Anaerobic conditions left organic material undigested. o Suspended solids inputs were inorganic material from upstream erosion and organic matter from wastewater discharge. (Fetter et al., 1978)
City of Clermont, Florida (Pilot study)	Freshwater marsh	Four 200 m^2 plots Loading rates of 1.3, 3.8 and 10.2 cm/wk	Total N 10½ month ave. of 1.14 kg/(ha)(d) Total P 10½ month ave. 1.19 kg/(ha)(d)	97.29% (NO_3 + NO_2) 97.5%	o Dead standing crop and below ground biomass acted as N sinks. o Storage in roots, litter and soil complex accounted for P reduction. (Zoltek et al., 1978)
City of Wildwood, Florida (Existing discharge)	Hardwood swamp	202 ha swamp area 672 ha watershed 570 m^3/d wastewater input	Total N 15.3 mg/l Total P 6.4 mg/l Wastewater Cu - 0.02 mg/l Fe - 0.17 mg/l Mg - 4.1 mg/l Pb - 0.03 mg/l Zn - 0.048 mg/l Urban runoff Cu - 0.01 mg/l Fe - 0.19 mg/l Mg - 3.2 mg/l Pb - 0.02 mg/l Zn - 0.015 mg/l	89.5% 98.1 - seasonal 13% annual (Ave. reduction for combined wastewater and urban runoff flow) Cu - no change Fe - 85% Mg - net increase Pb - 60% Zn - 75%	o High levels of N-removal during August and September attributable to plant utilization. o P release during dormant period responsible for lower annual removal efficiency. o All influent and control samples relatively low in metal content. No study of uptake or removal mechanisms. No discernible impacts on wetland. (Boyt et al., 1977)

(continued)

TABLE 5 (Continued)

System/location	Wetland type	Hydraulic/ hydrologic factors	Application concentration	Removal efficiency	Comments and reference
Brookhaven National Laboratory, New York (Artificial system)	Freshwater marsh-meadow pond systems	sewage loading of 80 m^3/d 60-80% recycled within system .2 and .4 ha systems pond - 1.5 m deep with 946 m^3 capacity meadows - 3% slope marshes .5-1m depth	Total N 25.2 mg/l NH_3-N 8.4 mg/l Kjeldahl-N 19.7 mg/l (NO_2+NO_3)-N 5.5 mg/l Total P 7.2 mg/l PO_4-P 4.8 mg/l Cr .05 mg/l Cu 0.7 mg/l Fe 3.6 mg/l Mg 4.3 mg/l Zn 1.3 mg/l BOD_5 170 mg/l SS 353 mg/l	79% 86% 81% 73% 77% 77% 60% 94 58% 23% 85% 88-92% 91.5	o Reductions are for the total system (meadow/marsh/pond). The removal abilities of the individual components have not been analyzed. o Meadow-marsh-pond system somewhat more effective than marsh-pond system. (Small and Wurm, 1977; Small, 1976)
Vermontville, Michigan (new system)	Artificial seepage wetland	4.6 ha diked irrigation fields 94,661 m^3 of effluent, June-October	Data on N not available Total P 1.8 mg/l (wastewater) Total P 2.1 mg/l (combined wastewater and wetland waters)	60% of NO_3 97%	o Reduction occurs through denitrification in the shallow wetland soil. o P removal occurs through soil adsorption of wastewater prior to encountering ground water. 95% occurs in upper 3 feet of wetland soil. (Williams and Sutherland, 1979; Sutherland and Bevis, 1979; Williams, 1980)

nutrients, a 51 percent reduction in concentration of nitrate and a 13 percent reduction for phosphorus were observed. Additionally, annual net retention of phosphorus, due largely to precipitation into organic sediments, was estimated to be perhaps as much as one-third of the amount entering the marsh. Removal of oxygen-demanding substances and suspended solids also showed very positive results. Despite the apparent success with natural systems, the researchers favor efforts to construct artificial marshes rather than discharging wastewaters to natural wetlands.

- **Great Meadows National Wildlife Refuge, Massachusetts**

In conjunction with feasibility studies of the overall concept of wetland disposal of wastewater in Massachusetts, Yonika and Lowry [1979] investigated the effects of an existing wastewater discharge to the Great Meadows National Wildlife Refuge in Concord. This freshwater marsh wetland has been the recipient of sewage discharges since the early 1900's. Concerns recently expressed about odor problems and organic impacts on the wetland prompted the investigators to select Great Meadows as a study site. Field investigations and evaluations were conducted with respect to wetland hydrology, nutrient dynamics, and water quality. Analyses were also conducted on sediment quality, invertebrate populations and vegetative community. Results of the testing program revealed:

(1) Great difficulty in attempts to model hydrology;

(2) Different renovating capabilities in different sections of the marsh and, more significantly, in different seasons of the year;

(3) Significant nutrient retention in the sediment;

(4) Dense luxuriant plant growth within a 60-to 75-foot radius of the wastewater effluent pipe and evidence of a "thermal plume" in winter;

(5) Predominance of pollution-tolerant tubificid worms within 250 feet of the discharge point; and

(6) Conditions at the marsh outlet to the Concord River similar to recovery zone downstream of a sewage discharge.

Southern Freshwater Marshes

Several investigators have examined the usefulness and impacts of wastewater disposal in freshwater marshes in the southeastern portion of the U.S. The studies have met with variable results.

o Clermont, Florida

Freshwater swamps and marsh areas were investigated in Florida with encouraging results. In 1977-78, a 10-month pilot study was conducted for the city of Clermont, Florida, to determine the effect of varied loadings of secondary wastewater effluent on the productivity, and nitrogen and phosphorus budget of a freshwater marsh [Zoltek, 1978]. The study site was within a 32-ha marsh, composed primarily of emergent aquatic macrophytes. Arrowhead, pickerel weed, panic grass and marsh hibiscus were the dominant species. The study successfully demonstrated the viability of utilizing the marsh as a tertiary system for upgrading wastewater effluent quality. Specifically, the initial year of operation showed major reductions in nitrogen and phosphorus, to concentrations comparable with background levels. The apparent reductions in phosphorus were due to accumulation and storage in the soil complex, roots and dead standing matter. Studies of soils and vegetation showed a possible higher rate of peat production and greater plant uptake of phosphorus and nitrogen in areas receiving wastewater discharges.

o Wildwood, Florida

In a University of Florida research study [Boyt et al., 1977], a hardwood swamp which had been receiving wastewater effluent and surface runoff from the City of Wildwood (population 2,500) for about 20 years was investigated. Three contiguous wetland areas totaling about 200-ha were examined. The wetland sequence consisted of a marsh community vegetated with duckweed, cattail and willow, followed by two hardwood swamps. Water quality studies showed reduction of nutrients through the wetlands to levels equal to or less than those in the receiving waters of Lake Panosoffkee and in an adjacent control swamp. High levels of nutrient removal were associated with increased productivity of vegetation in the swamp. Statistically significant growth rate increases were noted for cypress and ash. Unlike other wetland studies [Shih et al., 1979], nutrient buildup in sediments was not found. The inflow of urban runoff was suspected of causing disturbance of sediments in some areas of the wetland, resulting in inconsistent ammonia nitrogen readings. Relatively low concentrations of heavy metals in marsh and swamp waters reflected the low levels discharged from the sewage treatment facility.

Tidal Wetlands

In the late 1960's, Grant and Patrick [1971] undertook a field investigation of the Tinicum Marsh in Pennsylvania to assess the health and function of the tidal wetland ecosystem in relation to existing wastewater discharges. Three sewage treatment plants discharging into the marsh were known to be contributing to high organic loadings to the wetland. The main focus of the investigation was on nutrient assimilation, reoxygenation of surface waters and wetland productivity.

The chemical analyses and biological field studies confirmed damage to the marsh from the wastewater loadings. In particular, severe bacterial contamination, low oxygen and high nutrient levels were observed. Decreased species diversity in the Tinicum Marsh in comparison to a nearby undisturbed marsh provided evidence of biological damage.

Because of tidal flow and varying volumes of sewage discharges, the researchers found it difficult to assess the distribution of organic loads and the exact pollutant reduction efficiency of the wetland. It was observed, however, that significant reductions in BOD, phosphate, ammonium and nitrate occurred as a result of the tidal excursion of the river water over the marshland, in the time interval of about two to five hours. Although field data showed inconsistencies, probably due to the irregular flow pattern and pollution load mentioned previously, it was evident from the study that these particular marshlands make a significant water quality contribution through reduction of nutrient loads and increases in oxygen content.

CASE STUDIES OF NATIONAL WETLANDS TREATMENT OF SURFACE RUNOFF

Several major investigations which provide information on the effectiveness of wetlands as stormwater treatment systems are summarized in Table 6. They represent a wide diversity of wetlands types and geographical regions. Included are northern peatlands, cypress wetlands, a brackish marsh, high altitude meadows and wetlands detention basins. Brief descriptions of the various wetland-stormwater systems which were the subject of these investigations are provided below.

Natural Wetland Systems

- **Wayzata Wetland, Minnesota**

The Wayzata Wetland in Wayzata, Minnesota was recently investigated by Hickok et al., [Hickok et al., 1977], to evaluate the interactions of stormwater runoff in a wetland area and determine the potential usefulness of such areas in management of water quality. The study site was a 3.06-ha peat wetland, located in the center of the City of Wayzata (population 4,500), on the outskirts of the Minneapolis-St. Paul metropolitan area. The contributing watershed (26.3 ha) consisted of mixed urban, sparsely developed, and open wooded land uses. Inflow to the wetland consisted of direct precipitation (35 percent), surface runoff (47 percent) and ground-water inflow (18 percent). Water losses were through evapotranspiration (25 percent) and surface discharge (75 percent).

- **Lake Tahoe Meadowlands, California**

Morris et al., [Morris et al., 1980] recently conducted a one-year field investigation of the effectiveness of natural marsh and meadowlands to provide treatment of surface runoff in the Lake Tahoe Basin. Seven

TABLE 6. OBSERVED POLLUTANT REMOVAL EFFECTIVENESS OF WETLAND-STORMWATER TREATMENT SYSTEMS

System/location	Wetland type	Hydraulic/ hydrologic factors	Application concentration	Removal efficiency	Comments and reference
Wayzata, Minnesota (Existing runoff situation)	Peatland	28.3 ha watershed 2.8 ha wetland area Inputs: Precip. - 2.38 ha·m G.W. - 1.20 ha·m Runoff - 3.19 ha·m	(Annual average)		o Nutrient discharge from wetlands related to seasons.
			NH_3-N 3.94 mg/l	Net increase	o P seems to be limiting plant nutrient. Microbial activity appears to be initial and most important mechanism for P removal
			Total P .92 mg/l	78%	
			SS 701 mg/l	94%	
			Cd .4-1.4 μg/l	25-80%	o Heavy metal inflow concentrations and removal efficiencies varied according to contributing land uses. Greatest reduction values for commercial area runoff.
			Cu 12-19 μg/l	73-83%	
			Pb 26-71 μg/l	90-97%	
			Zn 10-15 μg/l	78-86%	(Hickok et al., 1977)
University of Central Florida	Cypress stand	9.76 ha watershed, with 67% impervious area.	Total N 45 Kg/yr.	95%	o Slow moving, circuitous flow allows particulate matter to settle and accumulate rapidly.
			Total P 8 Kg/yr.	97%	
			SS 22,580 Kg/yr.	99%	(East Central Florida Regional Planning Council, 1978; Lynard et al., 1980)
			BOD_5 145 kg/hr.	89%	
Montgomery Co., Maryland	Wetland detention basin	60 ha watershed 2.4 ha permanent pond with 45,600 m^3 dead storage capacity Depth - .9 to 4 m 22 hr. detention time @ peak inflow rate of 0.62 m^3/s.	NH_3-N 3 g/s	99%	o Large permanent pond volume is key factor in high pollutant removal efficiencies.
			Total P 0.3 g/s	99%	
			Ortho P 0.13 g/s	93%	
			BOD_5 5.2 g/s	97%	
			Cd 0.18 mg/s	98%	
			Fe 4.7 mg/s	96%	
			Pb 0.18 mg/s	96%	(Lynard et al., 1980; McCuen, 1978)
			Zn 0.23 mg/s	99%	
Lake Tahoe, California (Natural system)	High altitude meadows	Several sites investigated with watersheds of several hundred to 14,350 ha. Wetland slopes of 2-7%.	NH_3-N .02-.44 mg/l	Up to 67%	o Extreme variability in nutrient removal. Many instances of increase through wetland. Most significant reductions during storm episodes.
			NO_3-N .02-.57 mg/l	Up to 96%	
			TKN .2-6.6 mg/l	Up to 76%	
			Total P .018-1.9 mg/l	Up to 93%	o TKN released from wetland systems during spring snowmelt runoff.
			SS 1-2,978 mg/l	Up to 99%	o SS removal greatly enhanced by sheet flow conditions. (Morris et al., 1980)

systems consisting of four streams and three tributary drainage areas were investigated. The contributing watersheds consisted of a mix of urban, rural residential, pasture and forested lands. The primary focus of the study was on nutrient and sediment loadings associated with land development, road construction and other soil disturbance activities.

- **Cypress Stand-Orlando, Florida**

In connection with Section 208 water quality planning studies for Orange County, Florida, natural treatment of surface runoff through a cypress stand was investigated [East Central Florida Regional Planning Council, 1978; McCuen, 1978]. The wetland study site is located at the University of Central Florida and serves a drainage area of 9.76 ha, of which 67 percent is an impervious area. The wetland is characterized by marsh vegetation and small cypress at the exterior, and mature cypress with intermittent ponds and sloughs in the interior. Stormwater from the campus grounds is channeled into the cypress stand where it follows a circuitous, slow-moving path, leaving the wetland by means of surface outflow, evapotranspiration or soil infiltration. Analysis of treatment effectiveness focused in this study on BOD, suspended solids, nitrogen and phosphorous.

Constructed Facilities

- **Montgomery Mall Lake, Maryland**

Among the many stormwater detention and control facilities constructed in Montgomery County, Maryland since the early 1970's is the Montgomery Mall Lake [Lynard et al., 1980; McCuen, 1978]. This is an offsite storage/detention pond serving a 60-ha watershed. Included in the drainage area are a large shopping mall, several apartment complexes, townhouses, a major highway and several secondary roads. The pond is used to limit peak flows and to reduce surface runoff pollutants. The pond has a 2.4-ha permanent pool with 45,600 m^3 of dead storage capacity. The pond is designed to control an inflow of .62 m^3/s and to release the volume at about .06 m^3/s. Grasses and wetland vegetation line the edge of the pond. Pollutant removal efficiencies of the detention facilities have been reported by McCuen [1978].

WETLANDS TREATMENT CONCLUSIONS

Based on the analysis of Bay Area and national case studies, the following conclusions are made on wetlands treatment:

- The high productivity of a wetland allows it to utilize efficiently the nutrient inputs from surface runoff, however, removal of phosphorus is not as reliable compared to nitrogen uptake;

- Wetlands can act as sinks for heavy metals by immobilizing them in the sediment layers or storing them in inert form in plant tissues;

- Depending upon wetland type and pollutant loading, it appears that wetlands can readily tolerate and assimilate urban runoff pollutants, however, much more quantitative data is needed.

- Information on Bay Area wetlands that receive and treat urban runoff pollutants is limited - further study in this area is indicated;

- Wetlands have not been designed and constructed for the specific purpose of treating urban runoff, however, the potential for this type of system appears particularly suitable for the Bay Area.

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REGIONAL WETLANDS PLAN FOR URBAN RUNOFF TREATMENT

LEGISLATIVE REQUIREMENTS AND POLICIES IN THE SAN FRANCISCO BAY AREA

Technical Memorandum No. 88
December 2, 1982

"A town is saved, not more by the righteous men in it than by the woods and swamps that surround it."
Henry David Thoreau

Wetlands are now widely acknowledged as a valuable resource. They provide recreational opportunities in an aesthetically pleasing environment, productive wildlife habitat, flood control, groundwater recharge areas, and other benefits (1). Wetlands are effective water treatment systems (2). However, wetland areas frequently are also valuable in terms of their potential for development or agricultural use. In response to these diffuse interests, a myriad of legislative actions have been enacted to control wetland use and development. Numerous interest groups have also arisen in support of their contentions regarding the most appropriate use of wetlands.

The role of the major agencies directing wetland use and management is summarized below. Particular emphasis is given to these policies and legislation affecting the development and use of wetlands treating urban stormwater runoff. The status of many of the legislative programs and agency policies are capable of rapid change; only a few decades ago, a predominant value of wetlands was thought the potential for development through fill and channelization activities (1). Revisions in the major federal legislation currently are being pursued actively (3). However, the review presented in this paper provides a framework for understanding the forces now directing the use and development of wetlands and indicates the historical perspective which has resulted in the present regulatory system.

Comprehensive reviews and summaries of wetland law are available from several sources. For the preparation of this paper, reports from Kramer (4), California Department of Justice (5), University of Alabama Law Center (6), Shate and Mihaly (7), Spiszman (8) and the Association of Bay Area Governments (9), were used extensively in providing interpretations and clarifications of legislation and court decisions as well as providing direction for the review of appropriate documents.

FEDERAL AGENCIES

Army Corps of Engineers

The Army Corps of Engineers (COE) is the agency with the most prominent regulatory role over wetlands. Its authority dates back to the Rivers and Harbors Act (RHA) of 1899 (10). This act was primarily intended to protect "navigable waters of the United States" from obstructions. Section 10 of the Act requires a Corps permit prior to the creation of any obstructions to navigation or the construction of any structures in navigable waters. A permit is also required for any modification of a "navigable water of the United States" such as dredging and filling. A "Section 9" permit is required for the construction of any structure across a navigable water body.

A key point regarding the jurisdictional limitations of this act is the restriction to "navigable water of the United States". These waters include those rivers and lakes "Subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce" (11). This authority follows a series of court cases precisely defining the limits of the COE statutory responsibility over wetlands (12-16).

In the San Francisco Bay Area, a substantial area of potential or existing wetlands fall under the COE jurisdiction under the authority of the Rivers and Harbors Act. All Bayshore areas at elevations lower than mean high tide fall under RHA jurisdiction. This includes all historic wetland areas below this level, even if now dry. Areas above this boundary fall under traditional R&H jurisdiction only if activities affect navigation in the waterbody. The RHA gives little jurisdiction to the COE over small streams and creeks without navigational capacity. The limitation of authority over navigable rivers and streams to their ordinary high water mark results in control of their riparian habitats only to the extent that development or use will affect navigation and commerce.

The COE responsibilities for wetlands was greatly increased by the Federal Water Pollution Control Act Amendments (FWPCA) (17) of 1972, principally through section 404. The U.S. Environmental Protection Agency (EPA) was given primary responsibility for most water pollution control activities, but the COE (in recognition of its historic involvement) was given primary permit authority over wetlands. While the language of the act is similar to that of the RHA in designating authority over "navigable waters" the act defines "navigable waters" as "the waters of the United States, including the territorial seas" (18).

Section 404 gives the COE power to issue permits for the discharge of dredged or fill material into the waters of the United States (18). Wetlands are considered an integral part of these waters and are specifically included in COE and EPA regulations governing discharge. Thus, under section 404 requirements, the COE responsibility for wetlands extends above the mean high tide and ordinary high water limit. The exact definition of wetlands takes on great importance as used by the COE (and EPA) in determining the limits of "waters of the United States", which determines the limits of COE authority over discharge. In joint COE and EPA regulations, wetlands are defined as:

> The term "wetlands" means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas (19).

This definition limits the authority of the COE (and EPA) to lands that are generally "wet", unlike the authority under the RHA which extends jurisdiction up to historic mean high tide or ordinary high water regardless of current conditions. This limitation has important implications in the San Francisco Bay Area, granting no 404 regulatory authority to the COE over historic wetlands that are now dry.

There are several statutory exceptions to Section 404 requirements concerning the discharge of dredged or fill material:

(1) from normal farming, silviculture, and ranching activities such as plowing, seeding, cultivating, minor drainage, harvesting for the production of food, fiber, and forest products, or upland soil and water conservation practices;

(2) for the purpose of maintenance, including emergency reconstruction of recently damaged parts, of currently serviceable structures such as dikes, dams, levees, groins, riprap, breakwaters, causeways and bridge abutments or approaches, and transportation structures;

(3) for the purpose of construction or maintenance of farm or stock ponds or irrigation ditches, or the maintenance of drainage ditches;

(4) for the purpose of construction of temporary sedimentation basins on a construction site which does not include placement of fill material into the navigable waters;

(5) for the purpose of construction or maintenance of farm roads or forest roads, or temporary roads for moving mining equipment, where such roads are constructed and maintained, in accordance with best management practices, to assure that flow and circulation patterns and chemical and biological

characteristics of the navigable waters are not impaired, that the reach of the navigable waters is not reduced, and that any adverse effect on the aquatic environment will be otherwise minimized (20).

Of particular relevance to the San Francisco Bay Area is the limiting of COE authority over wetlands used for agriculture.

The COE policy governing wetland use, under the authority of the Rivers and Harbors Act and the Federal Water Pollution Control act, is generally restrictive of activities that may damage wetlands. The intent of the FWPCA is to prevent pollution of the nation's waters, thus giving the COE clear direction regarding its purpose in administering the section 404 wetland permit system. While the Rivers and Harbors Act was initially intended as protection of the navigational capability of the nation's waterways, the purpose of this Act has been increased by subsequent legislation and executive order. The National Environmental Protection Act (NEPA) of 1972 (21) requires all federal agencies to consider the environmental impacts of its actions, which includes its permitting authority. Thus, this Act requires that environmental effects be considered when the COE is using its permit authority under the RHA. The Coastal Zone Management Act (CZMA) of 1972 (22) also imposes environmental constraints upon application of COE authority under the RHA. The CZMA requires that federal agencies must conduct their activities affecting the coastal zone in a manner consistent, to the maximum extent possible, with a state's coastal management program. Since state programs are designed, at least in part, to provide environmental protection to the coast, this requirement puts an additional mandate on the COE to consider environmental consequences of its permit process under the RHA. Other important federal legislation that puts environmental restraints on the COE permit process include the Fish and Wildlife Coordination Act (23), the Wild and Scenic Rivers Act (24), the National Historic Preservation Act (25), the Marine Protection Research and Sancturies Act (26), the migratory Bird Treaty Act (27), the Anadromous Fish Conservation Act (28), the Marine Mammal Protection Act (29), the Fishery Conservation and Management Act (30), and the Endangered Species Act (31). Of particular importance in directing COE activities in wetlands is Executive Order No. 11990. This order directs federal agencies to "minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands" (32).

The COE regulations pertaining to granting permits under both the RHA and the FWPCA reflect the mandate to protect wetlands. Any modification of a wetland must be determined to be in the general public interest. Furthermore, any activity permitted in a wetlands must be demonstrated to depend on its location, with no available alternative location outside of a wetlands. The COE must consult with other Federal and State agencies in determining potential impacts of wetlands projects, most noteably the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the California Department of Fish and Game (32,33). Through interagency memoranda, a four layered review process is now routinely conducted prior to the issuance of a permit.

It is apparent that in the San Francisco Bay Area, the COE has both the authority and the mandate to protect wetlands. Development is not prohibited in wetlands, but to be approved, any action must be in the general public interest and must depend on a wetland environment. Bay shore lands are under RHA authority below mean high tide level, and under Section 404 authority if their condition is coincident with the COE definition of wetlands. Inland areas clearly fall under RHA jurisdiction if within normal high water in a navigable water. Only Section 404 authority is normally applied to upland wetlands. Some confusion exists regarding the use of Section 404 authority over upland riparian zones. While the U.S. District Court in Louisiana ruled that clearing of riparian forest was under the jurisdiction of the COE under Section 404 (34), the COE has failed to incorporate this precedent in its general policies (35). Thus, COE actions in accepting responsibility over upland riparian zones in the Bay Area are not certain.

Section 404 of the FWPCA is currently under review which could result in amendments substantially altering both the permit process and the criteria by which projects are evaluated. Several major reforms have been approved by the Presidential Task Force on Regulatory Relief during 1982 which would change important elements of the current role of federal agencies in regulating wetlands (36). The main stated purposes of these reforms are to streamline the permitting process, allowing more rapid granting of permits and providing accountability for final permit decisions with the Corps of Engineers. These reforms would also provide fewer opportunities for other federal agencies to review proposed projects and would eliminate the veto power of the U.S. Environmental Protection Agency and the "de facto" veto power of the U.S. Fish and Wildlife Service over the issuance of a COE permit. Final action regarding these reforms has not yet been taken.

U.S. Environmental Protection Agency

The Federal Water Pollution Control Act of 1972 (17) gave the Environmental Protection Agency (EPA) the responsibility of protecting the quality of the nation's waters. In 1973, the EPA published a policy statement regarding its role as an advocate of preserving and protecting wetland systems (37). However, Section 404 of the FWPCA requires the COE rather than the EPA to issue permits for the discharge of dredged or fill materials, thus giving the COE the primary responsibility over wetlands. However, EPA has veto power over the COE permit, thus preserving final EPA authority over any activity in a wetlands as defined in joint COE/EPA regulations. This power of veto applies only to wetland permits under Section 404 jurisdiction, it does not extend to permits and policies under the Rivers and Harbors Act. Under Section 404 (b)(1), environmental guidelines followed by the COE in evaluating permit proposals are developed by the EPA. Thus, the statutory power of the EPA provides both for establishing appropriate environmental criteria for granting permits, and for prohibiting projects that do not meet these criteria.

Other sections of the FWPCA give the EPA responsibilities over pollutant discharge from point and non-point sources which have direct impact over wetlands and general water quality. In California these programs have been assumed by the State Water Resources Control Board and the Regional Water Quality Control Boards and will be discussed in relation to these agencies.

Fish and Wildlife Service

The U.S. Fish and Wildlife Service (FWS) must be consulted on any federal project that involves modification of any body of water in the United States pursuant to the Fish and Wildlife Act of 1958 (23). While the FWS is a nonregulatory agency, the COE is required to place "great weight" on the FWS comments when considering the granting of permits (23,32). Thus, for almost all projects under COE jurisdiction, the FWS holds a substantial power over the project should it find serious problems of environmental degradation.

The FWS plays an active role in promoting wetlands. In 1977 it held a National Symposium on wetland protection (38) and in 1978 published a report examining state and local laws protecting wetlands and suggested improvements (39). In 1979 it sponsored a national inventory focusing on the characteristics and extent of wetlands and appropriate management (40). Also during 1979, the FWS published a study done jointly with the California Department of Fish and Game "Protection and Restoration of San Francisco Bay Fish and Wildlife Habitat" (41). In this study, existing wetlands were mapped according to the FWS classification system. Historical margins of the San Francisco Bay were also mapped. This mapping helps to define current COE jurisdiction over historic lands below mean high tide.

The role of the FWS in the San Francisco Bay area with regard to wetlands is substantially different than that of the COE and the EPA. The FWS is not a permitting agency but serves more as an advocate of wetlands preservation and restoration. It holds almost "de facto" veto authority over permit authorization and are consulted on any wetland project under COE authority. Thus, it plays a major role in determining the future of wetland development in the San Francisco Bay Area.

National Marine Fisheries Service

The National Marine Fisheries Service (NMFS) functions as a commenting agency in a similar manner to the U.S. Fish and Wildlife Service. The NMFS reviews federally initiated, licensed or permitted projects which "have the potential of altering aquatic environments and thereby impacting the biological resources which depend upon those habitats" (42). The policy of the Southwest Region of the NMFS, whose jurisdiction includes the San Francisco Bay Area, is to "not recommend approval or authorization of any project or activity that will damage any existing or potentially restorable habitat of living marine, estuarine, or anadromous resources" (42).

Some exceptions to this general policy are allowed if adequate compensation is made for the damaged habitat. The following conditions are required to be granted an exception:

1. The project will incorporate all feasible modifications and construction techniques to eliminate or minimize adverse environmental impacts;

2. An acceptable combination of habitat restoration, enhancement or off-site acquisition will be adopted to compensate for adverse environmental impacts that cannot reasonably be eliminated by project modification;

3. Post-project habitat value shall be equal to or greater than pre-project habitat value. Determination of post-project value will be based on the contribution of that habitat to the support of commercial and recreational fisheries, fishery resources, certain marine mammals, and/or endangered species (42).

The NMFS serves as a source of technical expertise and guidance to the Corps of Engineers in granting permits for projects potentially impacting wetlands. However, the COE is not bound to follow the NMFS suggestions. The NMFS generally serves as an advocate for wetland restoration and development, particularly in salt water systems.

The NMFS are a likely agency where strong support may be obtained for projects restoring or creating salt water marshes. Its interest, expertise and jurisdiction usually does not extend to inland riparian zones or upland wetlands.

STATE AGENCIES

Department of Fish and Game

The California Department of Fish and Game (DFG) is responsible for the fish and wildlife resources of the state (43). This responsibility with regard to wetland development is generally performed by commenting and advising permit agencies. The Fish and Wildlife Coordination Act requires that Federal agencies with permit authority consult with the state department responsible for wildlife (23). Thus, DFG comments on wetlands projects under COE review following both Rivers and Harbors Act and "Section 404" authority. Comments and review of wetlands projects by the DFG are usually done in cooperation with the United States Fish and Wildlife Service. The DFG has direct permit authority in the event of a proposed project that will alter a streambed (42).

The Department of Fish and Game is a strong proponent of wetlands preservation and restoration. It serves as the primary state agency protecting wildlife resources and is mandated to consider the management of habitat as a feature of wildlife survival (42). Other state legislature and executive orders also direct the DFG to protect wetlands. These acts are generally analogous to federal acts governing

federal agencies. The California Environmental Quality Act (CEQA) (43) requires the preparation of an environmental impact report for all projects involving public agencies. The DFG has the opportunity to comment on any EIR that may result in a significant adverse effect on the environment. The Resources Agency Basic Wetlands Protection Policy (45) prohibits the authorization of projects that fill, harm, or destroy wetlands subject to specific exceptions. These exceptions occur only if the project:

1. is water dependent or an essential transportation, water conveyance or utility project

2. has no feasible, less environmentally damaging alternative location

3. does not adversely affect the public trust

4. includes adequate compensation for project-caused losses (45).

The Keene-Nejedly California Wetlands Preservation Act of 1976 (46) also provides direction regarding the preservation and restoration of wetlands. This act recognizes the importance of the remaining wetlands and states the need for policy and programs to preserve, restore and enhance wetlands. Furthermore, this act directs the DFG to conduct a study to identify those wetlands which should be acquired or protected.

The DFG frequently serves as a liason by which private groups can provide input into the permitting process. They may seek information or respond to comments from such organizations as the Audubon Society and California Waterfowl Association with regard to specific projects. As a strong proponent of wetlands, they may incorporate information from numerous environmental interests in preparing comments prior to the issuance of federal permits.

State Water Resource Control Board and Regional Water Quality Control Boards

The State Water Resources Control Board (SWRCB) and the nine Regional Water Quality Control Boards (RWQCB) have been authorized by the Porter-Cologne Water Quality Control Act to serve as the principal state agencies responsible for water quality throughout the state (47). This responsibility extends over all "waters of the state" as defined any water, surface or underground, including saline waters, within the boundaries of the state" (47).

The Environmental Protection Agency has delegated many of its responsibilities under the Federal Water Pollution Control Act to the State of California. Thus, the SWRCB and RWQCB have the charge of ensuring that the provisions of the FWPCA are enacted and enforced.

The SWRCB sets state policy for water quality control. A provision of this policy is given highest priority to "improving or eliminating discharges that adversely affect...

(1) wetlands, estuaries, and other biologically sensitive sites

(2) areas important for water contact sports

(3) areas that produce shellfish for human consumption

(4) ocean areas subject to massive waste discharge (48)."

The SWRCB is further directed to protect wetlands following the Keene-Nejedly California Wetlands Preservation (46) Act and the Resources Agency Basic Wetlands Protection Policy (45).

The SWRCB also is responsible for the appropriation of water throughout the state. In acting upon appropriation applications, appropriations must be considered with regard to public interest. An application to appropriate unappropriated water must be filed by anyone who intends to divert water for use on non-riparian land, or to store in a reservoir for later use on either riparian or non-riparian land, from "surface streams and other surface bodies of water and in subterranean streams flowing through known and definite channels (49)." Furthermore, the SWRCB must notify the California Department of Fish and Game of any appropriation permit application (50). DFG then has the opportunity to recommend the amount of water needed for the preservation and enhancement of fish and wildlife resources. While the SWRCB is not required to follow these recommendations, these comments do serve as a technical data base to assess the potential impact of projects on wetlands and other aquatic habitats.

Each regional water quality control board is required to formulate and adopt a water quality control plan for their region (51). The San Francisco Bay Regional Water Quality Control Board has adopted the San Francisco Bay Basin Plan, with amendments being formulated during 1982. In this Basin Plan, a policy has been adopted to allow the use of wastewater to create or enhance wetlands (in contrast to the general policy prohibiting the discharge of wastewater into confined water and into areas at which the wastewater will not receive a minimum initial dilution of at least 10:1) followed the general policies that:

1) The prospective discharger demonstrate that "environmental benefits will be derived as a result of the discharge (52)."

2) The prospective discharger demonstrate that "full and uninterrupted protection will be given to all beneficial uses which could be made of the receiving water in the absence of point source discharges and that there will be a creation of new beneficial uses or fuller realization of existing uses beyond that which would occur in the absence of point source discharges (52)."

3) "Marshlands created using wastewater shall be fully protected as water of the State, and waste discharge requirements and/or NPDES permits will be established for the discharge before it enters the marsh (52)."

4) "The Regional Board will require that the maximum benefit be derived from the quantity and quality of water that is available (52)."

5) "The prospective discharger must demonstrate "(1) a commitment, for the life of the project, of an adequate amount of land to make optimum use of the water to be committed to marsh creation; (2) a commitment, for the life of the project, to manage the marsh to provide for maximum environmental benefit; and (3) that acceptable reclamation or disposal facilities are available for any wastewaters not committed to marsh creation (52)."

6) The prospective discharger demonstrate that "the marsh will be managed so as not to create vector control problems, botulism, or nuisance (52)."

7) The prospective discharger must "provide a management plan which provides detailed information on how compilance with Policies 1 through 6 is to be achieved (52)."

8) "Pilot investigation will be required to determine the information to develop a management plan unless the applicant can provide the information without such investigations. The necessity for pilot work, however, will not be allowed to interfere with the implementation of necessary wastewater facility programs (52)."

The Basin Plan contains no specific reference to wetlands created through the use of stormwater runoff. In a 1981 letter from the executive officer of the San Francisco Bay RWQCB to the Association of Bay Area Governments, the RWQCB stated that newly created marshland used to treat urban runoff may not be considered waters of the State (53)." However, discharge from an artificially-created wetland would have to meet requirements consistent with Basin Plan objectives to avoid environmental degradation. Similarly, no specific reference is made in the plan to riparian zones.

The RWQCB issues National Pollutant Discharge Elimination System (NPDES) permits following the authority of Section 403 of the Federal Water Pollution Control Act (16). In issuing a permit, the RWQCB must ensure that no state or federal water quality laws will be violated. In addition, discharge permits are granted with regard to the attainment of the water quality goals described in the Basin Plan. The RWQCB also is responsible for implementing the Basin Plan and enforcing discharge permit requirements (54)."

Under provisions of the FWPCA, wetlands are indicated as a possible important component toward accomplishing water quality objectives. Sections 201 and 204 mandate that nonpoint pollution sources must be controlled on an areawide basis, that water treatment management should encourage systems combining "open space" and recreational considerations and that alternative waste management techniques must be studied and evaluated prior to the issuance of grants for treatment works. These provisions, coupled with section 208 requirements for areawide waste treatment management plans, should encourage the development of stormwater treatment wetlands. However, these elements of the FWPCA

have not been aggresively pursued. Most water pollution control activity has been directed toward point source discharges through the NPDES permit system. The San Francisco Bay Basin Plan contains little regarding nonpoint source control. Yet, water quality objectives" to restore and maintain the chemical, physical and biological integrity of the Nation's water" (17) may not be achievable considering only point source dischargers. While the SWRCB and the RWQCB have jurisdiction over many aspects of wetland use and development, their input in the San Francisco Bay Region has not been significant in this field. These Boards have functioned primarily as regulatory agencies protecting water quality in existing wetlands rather than as active participants or proponents of wetlands serving large scale water quality objectives.

State Lands Commission

The State Lands Commission has authority over all tidal and submerged lands and beds of navigable waters owned by the state (55,56,57). These lands became the property of the state when California was admitted to the Union. Some of this land has subsequently been purchased by private parties or assigned to local governments.

The State Lands Commission issues leases and permits for use of these lands. These leases and permits must conform to the principles of public trust; the preservation of the public right to commerce, navigation and fisheries. The public trust doctrine exists over those lands which have not been filled regardless of current ownership. The State Lands Commission conforms to the general state doctrine established through CEQA (44), the Keene-Nejedly California Wetlands Preservation Act (46), and the Basic Wetlands Protection Policy (45) in providing environmental protection to wetlands for the public good.

The recent passage of AB 1418 in September, 1982 established a Land Bank fund for financing state acquisitions "of wetlands, marshes, overflowed and submerged areas, or adjoining areas (58)." The State Lands Commission acts as the trustee of this fund and of the acquired lands. This act establishes a mechanism for the State to acquire land as a compromise measure to resolve title disputes and to facilitate "the adoption of mitigation measures for projects having a significant impact on certain environmentally sensitive areas, including wetlands."

Much of the wetland around the San Francisco Bay Area has been assigned and is no longer under jurisdiction of the State Lands Commission. However, some tidelands, swamps and overflow lands are still administered by the Commission. Its policy of wetlands use provides for greater protections on sloughs and creeks than on tidal lands. Generally, creeks and sloughs are considered appropriate for restricted or limited use, recognizing significant environmental values and generally minimizing public use. Tidelands are generally considered more appropriate for multiple use, which while retaining significant environmental values are less susceptible to environmental degradation (59).

California Coastal Commission

The California Coastal Commission (CCC) is responsible for regulating all development within the state coastal zone. This authority derives from the Coastal Act of 1976 (60). The coastal zone is defined as the area extending three miles seaward and inland generally 1,000 yards. Certain areas are excluded, including those areas under the jurisdiction of the San Francisco Bay Conservation and Development Commission.

The Coastal Commission adopted in 1981 its "Statewide Interpretive Guidelines for Wetlands and Other Environmentally Sensitive Habitat Areas (61)." This guideline describes the general CCC policy for protecting wetlands and the conditions under which development will be allowed. Wetlands and estuaries are afforded the most stringent protection of all sensitive habitat areas specifically addressed in the Coastal Act. Only those developments and activities listed below are permitted in wetlands and estuaries by the CCC (61):

1. Port facilities

2. Energy facilities

3. Coastal-dependent industrial facilities, such as commercial fishing facilities.

4. Maintenance of existing or restoration of previously dredged depths in navigation channels, turning basins, vessel berthing and mooring areas, and boat launching ramps.

5. Incidental public service purposes which temporarily impact the resources of the area, which include, but are not limited to, buying cables and pipes, inspection of piers, and maintenance of existing intake and outfall lines (roads do not qualify).

6. Restoration projects

7. Nature study, aquaculture, or similar resource-dependent activities.

8. In wetland areas, only entrance channels for new or expanded boating facilities may be constructed, except that in a degraded wetland, other boating facilities may be permitted.

9. New or expanded boating facilities

However, permitted projects must meet three statutory requirements (61):

1. Diking, filling, or dredging of a wetland or estuary will only be permitted if there is no feasible less environmentally damaging alternative.

2. If there is not feasible less environmentally damaged alternative, feasible mitigation measures must be provided to minimize adverse environmental effects.

3. Diking, filling or dredging of a wetland or estuary must maintain or enhance the functional capacity of the wetland or estuary.

The Coastal Commission has strong powers and direction toward the preservation and restoration of wetlands. These powers generally apply in the San Francisco Bay region only along the Pacific Coast. Much of its area of responsibility overlaps with that of the COE. However, in those areas under its jurisdiction, the Coastal Commission plays an important role in controlling wetland use.

California Coastal Conservancy

The California Coastal Conservancy was established to implement "a program of agricultural protection, area restoration and resource enhancement in the coastal zone within policies and guidelines established pursuant to Division 20" (Coastal Act) (62). In the San Francisco Bay Area, "restoration and resource enhancement in the coastal zone" to a large extent takes the form of wetland restoration and enhancement.

The criteria is somewhat flexible which the Conservancy uses to select and support projects. By statute, the Bay Conservation and Development Commission may adopt a list of priority areas and concerns providing guidance to the Conservancy (63). However, no formal selection procedure has been developed. Through conversation with Conservancy staff, some general selection criteria can be identified used to evaluate project proposals (64).

Important considerations in evaluating project proposals are (1) the benefit to the resource, (2) the cost effectiveness of the project and (3) the visibility and access of the project. Resource benefits include considerations of the habitat value with respect to the types of wildlife it will support and the prevalence of this habitat type in the region. Cost effectiveness considerations account for the limited financial support available from the Conservancy. Projects which can use cooperative agreements, matching funds or other means of minimizing the Conservancy financial commitment will encourage Conservancy support. The Conservancy also is concerned with the value of the proposed project to the community. Projects having a high visibility with easily discernible aesthetic values and use as an educational resource will have a high project priority.

REGIONAL AND LOCAL AGENCIES

San Francisco Bay Conservation and Development Commission

The San Francisco Bay Conservation and Development Commission (BCDC) has responsibilities for the shoreline of San Francisco Bay

similar to that held over the coast by the California Coastal Commission (65). BCDC has four main areas of responsibility:

1. To regulate filling, dredging and changes in existing uses of the San Francisco Bay, San Pablo Bay, Suisun Bay and all sloughs that are part of the Bay system and certain creeks and tributaries.

2. To regulate a 100 foot strip extending inland from the Bay under the guidelines of maximizing public access to the Bay to the maximum extent feasible ensuring that existing shoreline is reserved for use in fulfilling the designated high priority purposes of these lands. These priorities are for: ports; water-related industry; water-related recreation; airports; wildlife areas; and desalinization and power plants.

3. To have limited jurisdiction over any proposed filling of salt ponds or managed wetlands not subject to tides of the Bay. BCDC is authorized to ensure that any development in these areas provides public access to the Bay and retains the maximum amount of feasible water surface.

4. To implement with local government and the California Department of Fish and Game the Suisun Marsh Preservation Act of 1977. This act provides for a local protection program which must (65):

1. protect the wetlands within the Marsh
2. protect agricultural lands within the Marsh
3. designate permitted land uses within the Marsh
4. limited erosion, sedimentation and water run-off
5. protect riparian habitat
6. ensure that the use of the water-related industrial and port area in Collinsville be in conformity with the Protection Agency.
7. ensure that new development in the Marsh be designed to protect the visual characteristics of the Marsh .

In the San Francisco Bay Area, BCDC is a major force in regulating and promoting wetlands. However, its jurisdiction is restricted to those areas within 100 feet of the Bay. The effective regulatory area of control may extend over areas greater than this strip, since large projects bordering the Bay must get a permit from BCDC if any portion of their project falls within this 100 foot area. However, this 100 foot strip is considerably less than the California Coastal Commission jurisdiction extending inland 1000 yards to three miles seaward on the California coast. BCDC also has little control over upland wetland areas or riparian zones.

Counties and Cities

Counties and cities have within their authority provisions which can be applied to wetland protection such as zoning restrictions and subdivision controls. They have direct permit authority over projects occurring within their jurisdiction. Wetlands can also be designated as protected areas in jurisdictional general plans. In a review conducted

by BCDC, five or six local jurisdictions were identified with some form of protection for diked wetlands. However, a review by the Association of Bay Area Governments revealed that little jurisdiction is taken by local agencies in the San Francisco Bay Area over upland riparian zones (66). Generally, counties and cities are not active in promoting wetland control. Specific county plans regarding wetlands are reviewed in greater detail in ABAG Technical Memorandum No. 89 (67).

Special Districts

Various special districts may take an active interest in wetlands and have some regulatory authority. The Mosquito Abatement Districts may enter a wetlands to perform mosquito abatement activities and bill the property owner (68). These Districts frequently serve as advisors on proposed projects in order to avoid future problems that would arise if mosquito control mechanisms are not considered in project design.

Park Districts own substantial amounts of wetlands and land suitable for wetland development and restoration. The maximum development and use of wetlands frequently coincides with the optimal use of these lands as determined by the Districts; wetlands provides many of those values desirable in a park. Some parks have within their general plans goals to acquire and/or develop additional wetlands.

County Flood Control Districts own or control relatively large areas of wetlands or lands suitable for wetlands. Their basic mandate of providing protection from flooding is frequently compatible with the use of their lands as wetlands. Flood control basins can function as seasonal wetlands without losing storage or flow capacity. Continuous maintenance activities such as dredging of channels and levee stabilization near waterways provide opportunities for flood control districts to be an active participant in wetlands creation.

SUMMARY OF LEGISLATIVE AUTHORITY OVER WETLANDS DEVELOPMENT IN THE SAN FRANCISCO BAY REGION

General Authority over Wetlands

Many agencies at all levels of government have responsibilities for wetlands. The major permit authority over wetlands, granted under "Section 404" of the Clean Water Act and to a lesser extent the Rivers and Harbors Act, is given to the Army Corps of Engineers. General guidelines under which the Corps should grant permits is established through federal directives and legislation. However, specific references to wetlands and permit granting criteria are to a large part incorporated in Corps and Environmental Protection Agency regulations rather than though congressional and executive decree. The general policy followed in granting a permit is that the project must be in the general public interest and that the project must be located in or near a wetlands with no feasible alternative site available.

Several federal agencies take an active part in the review process before the Corps will grant a permit. These agencies consider and evaluate the environmental effects of a proposed project. The U.S. Fish

and Wildlife Service hold almost a "de facto" veto power over projects should they find environmental objections. The Environmental Protection Agency can withhold a permit should they find objections to a project requiring a "Section 404" permit. Other federal agencies participate as advisors to the Corps as projects come under their jurisdiction or mandate. All federal agencies must consider the requirements of NEPA and Executive Order 11990 when reviewing projects potentially influencing wetlands.

While the Army Corps of Engineers is the major federal permitting agency, they serve primarily to review projects proposed by other groups or individuals. Other federal agencies, noteably the Fish and Wildlife Service and the National Marine Fisheries Service, serve more actively as proponents of wetland development and restoration.

The State does not have a strong regulatory authority over wetlands similar to the federal government. Permit authority is given to the Department of Fish and Game only in the event of streambed modification. The California Coastal Commission holds permit authority over the ocean shoreline and to a lesser extent the San Francisco Bay Conservation and Development Commission grants permits for the development of Bay shoreline. The State Lands Commission controls the use of certain lands that have not been obtained by private parties or groups. However, its authority is fairly limited and applies to a relatively small amount of land. Of great importance is the general lack of jurisdiction by the state agencies over inland wetlands such as riparian zones bordering waterways and over potential wetlands. The State Water Resources Control Board and Regional Water Quality Control Boards have powers and the mandate to ensure adequate water quality in all waters of state. However, most of their activity has been directed toward dischargers rather than the active management of waterways to satisfy regional water quality objectives.

State agencies play an additional important role as advisors to permitting agencies. Under provisions of the Fish and Wildlife Coordination Act, the comments of the Department of Fish and Game are taken into consideration while reviewing permits for activities involving wetlands. Other state agencies may also comment on projects and provide important information regarding the public interest and possible environmental effects. State agencies frequently serve as a liasion enabling private groups to comment on proposed projects during federal review process.

Local governments and special districts also play an important role in regulating wetlands. Considerable influence on the disposition of a wetland or potential wetland can be enacted through local zoning and planning ordinances and guidelines. Special districts often have control over sizeable land areas which may be amenable to multiple use including wetland development and maintenance. Local governments and special districts can play an active role as promoters of wetlands through both their standard policies and through active involvement on an individual case basis. However, many local jurisdictions have not adopted specific policies regarding wetland use.

While there are multiple and often overlapping regulatory powers over many aspects of wetlands use, with a fairly comprehensive system of obtaining and incorporating comments from appropriate agencies, there is little large-scale planning for the San Francisco Bay Area. Permits and comments are obtained on a individual project basis, frequently with little regard to the overall needs of the region. For example, selectively permitting development only on certain wetlands types, or allowing wetland mitigation to take the form of a consistent exchange of wetland types could result in an abundance of one type of wetland habitat at the expense of another. On a case-by-case basis, substituting one wetland type for another may appear to be in the public interest and not result in environmental degradation, but the diversity of available habitats to the entire region could be reduced. This activity could take the form of filling fresh and brackish water marshes while creating or expanding salt water marshes. Fresh and brackish water marshes support different communities than are found in salt water marshes, so excessive trade-offs of this nature could result in the loss of valuable species to the region.

Authority over Seasonal Stormwater Treatment Wetlands

Jurisdiction over seasonal wetlands utilizing and treating urban stormwater runoff appears limited and highly variable. In developing, restoring or preserving wetlands receiving urban runoff, regulatory requirements will have to be evaluated on a case by case basis to determine permit requirements. Jurisdictional responsibilities may frequently be controversial since there is little precedent or legislation specifically addressing seasonal wetlands.

Federal jurisdiction over a wetland is most clear cut if the wetland is located within the mean high tide of a tidal water, within the ordinary high water mark of a navigable river or lake or is clearly an existing wetlands. If any of these criteria are met, the Army Corps of Engineers is obligated to issue a permit for any modification of the site imposing its authority under the Rivers and Harbors Act and/or Section 404 of the Clean Water Act. Although the COE would have regulatory responsibilities in these areas, it currently has no comprehensive policy nationally or specifically for the San Francisco Bay Area regarding seasonal wetlands receiving runoff. Any plan for a seasonal wetland would have to be evaluated on a case by case basis which gives no guidance in predicting the general acceptability of a project.

In an area with an existing wetland, it would be difficult to predict the response to a project proposal to utilize the area to treat urban runoff. The nature of the wetland might change from salt or brackish marsh to seasonally fresh, which would constitute a major change in habitat. It would be difficult to evaluate changes of this nature with regard to what best protects the general wetland resource and what is in the public good. Commenting agencies are likely to have widely different opinions; the National Marine Fisheries service would probably be more inclined to favor salt marshes while the California Department of Fish and Game may place a higher value on freshwater systems.

Federal permit authority generally would not extend over proposed sites for seasonal wetland development in upland areas that are currently not characterized as wetlands. Riparian zones, flood plains and historic wetland sites could potentially be developed without federal intervention. Upland wetlands could be regulated as point source discharge points subject to NPDES requirements.

The State of California has relatively little authority over the development of seasonal wetlands. The CCC and BCDC have permit authority over shoreline areas, but they have no general plan that accounts for seasonal wetlands. Similar to the problems with federal permitting of wetlands projects, there exists no comprehensive plan from which to evaluate the value of a project with respect to existing wetlands and other land uses. The State Lands Commission has authority over tidal and submerged lands and beds of navigable waterways owned by the state, which may put some restrictions on wetland development. The California Department of Fish and Game requires stream modifications which may occur in seasonal wetland construction projects. The SWRCB and RWQCB have responsibilities for the quality of the water in the State and implement the Federal Water Pollution Control Act. However, the State has relatively little power over the development of wetlands using urban runoff in upland areas. Perhaps more importantly, the State has no general policy controlling the quality of urban stormwater runoff which would provide incentives for wetland development.

Local governments, agencies and special districts can play a important role in wetland development and preservation. Potential wetlands under their jurisdiction or influence can frequently be managed for multiple use, including use as an urban stormwater treatment system. However, there is no general incentive for incorporating urban stormwater treatment into local planning. Treatment of stormwater serves to protect the health of the San Francisco Bay, with little observable immediate benefit to the local entity. No general plan exists that provides guidance regarding the needs of specific site development with respect to the overall environmental health of the region. Such a plan should be contained within the San Francisco Bay Area Basin Plan.

Currently, it is at the local level that the most opportunity exists for enhancement and creation of wetlands, particularly in upland areas.

Conclusions

The development of wetlands to treat urban stormwater runoff in the San Francisco Bay Area appears largely unregulated or promoted by the major agencies responsible for managing and protecting wetlands. Authority over activities in potential sites is strong only in areas currently considered as wetlands, or in lowlands historically subject to tidal flows or high water. Upland areas appear regulated with regard to wetland development only in respect to their ultimate impact on water quality as a point source discharge and in respect to their general environmental efforts following provisions of the California

Environmental Quality Act. Local agencies, governments and special districts have powers over many discrete land areas that could potentially be developed as wetlands, but they have neither the incentive nor the direction to generally consider development of treatment wetlands.

Urban runoff treatment wetlands hold the potential of providing a valuable function of enhancing water quality while retaining the multiple uses of a wetlands. It is important that both a plan be established to maximize the utility of these systems throughout the region and that specific regulatory requirements be defined to enable instigators of projects to determine the reception of any proposed project. It is also important that an incentive system be established to promote local entities with powers over local sites to develop these areas for the general public welfare.

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REGIONAL WETLANDS PLAN FOR URBAN RUNOFF TREATMENT

POLICIES AND OPPORTUNITIES FOR LOCAL AND REGIONAL INVOLVEMENT IN THE SAN FRANCISCO BAY AREA

Technical Memorandum No. 89
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I. INTRODUCTION

The many values inherent in wetlands have led to an increasing demand for restoration and development of wetland habitat (1,2). Federal and state legislation generally regulate activities in existing and historic wetlands with little authority over other potential areas for wetland development. Furthermore, federal and state agencies tend to serve primarily in a regulatory or review capacity rather than as promoters and developers of wetland projects. Specific reference to the development of urban stormwater treatment wetlands is largely ignored in existing legislation and policy (3). The opportunity and incentive for urban stormwater treatment wetland development appears greater at the regional and local levels of government. Special interest groups also can play a major role in instigating wetland restoration and creation projects.

The San Francisco Bay Conservation and Development Commission (BCDC) has prepared a review of local government planning and regulatory protection over land use and development in historic tideland areas (4). A summary of their results is shown in Table 1. In this review, a case-by-case examination of specific sites identified in their "Diked Historic Baylands Study" was made with regard to zoning and general plan land use designation and policies. Upland sites with potential use for the creation of urban stormwater treatment marshes are very diverse, and a similar case-by-case evaluation would not be worthwhile. A more practical evaluation of local planning and protection over potential sites for urban stormwater treatment marshes should first examine goals and provisions of general plans and determine how upland marshes would fulfill objectives of these plans. A preliminary set of potential sites for wetlands development have been identified, negating jurisdictional

TABLE I - LOCAL PROTECTION OF FORMER TIDELANDS (4)

Jurisdiction	Specific Wetland Gen. Plans or Zoning	Quasi - Protective: General Plan: BL SL TP	General Plan: AG	General Plan: OS PK	Zoning: AG	Zoning: OS	Zoning: FP	Ownership	None or Inef-fectual
Alameda Co.									
Alameda									x[1]
Fremont				0[2]	0		0	x	
Hayward	x								
Newark									x
Oakland (Port)									x
San Leandro									x
Union City								x	
Martinez									x
Contra Costa Co.									x
Richmond									x
Pinole				x		x			
Marin Co.	x								
Corte Madera	x								
Larkspur									x
Mill Valley									x
Novato		0	0	0	0			x	
San Rafael									x
Napa Co.			x	x	x		x		
Napa									x
San Mateo Co.									
Foster City									x
Menlo Park	x								
San Mateo		x	x	x		x			
So. S. F.									x
Redwood City									x
Santa Clara Co.	x								
Palo Alto									x
San Jose									x
Sunnyvale		x		x				x	
Solano Co.	x								
Vallejo									x
Sonoma Co.			x	x	x		x	x	
Petaluma									x

x[1] = applies   0[2] = uncertain if protection is effectual
AG = agricultural OS = open space FP = flood plain BL = bayland SL = shoreline
PK = park TP = tidal plain

intent, using the criteria of general physical suitability, appropriate urban stormwater supply and lack of current industrial or residential development (5). Identification of these potential sites, coupled with identification of favorable jurisdictional policies, should enable an effective initial determination of probable sites for wetland development. Following the identification of these sites, current zoning and land use designation can be researched in greater depth to determine the feasibility of wetland creation on specific sites.

Local government jurisdiction to control land use is provided by the State Planning and Zoning Law (6) and the Subdivision Map Act (7). The Subdivision Map Act gives the local government authority to cluster development to fulfill local goals. The State Planning and Zoning Law requires each local jurisdiction to adopt a general plan to serve as a guide of general development policies and land use objectives. Specific elements are mandated for inclusion in a general plan. Policies most likely to affect wetlands should be found in the conservation, open space, recreation and seismic safety elements. In this paper, appropriate elements of the general plans are reviewed for the nine Bay Area counties to determine where and if general policies exist that would favor creation of urban stormwater treatment marshes.

While local jurisdictions provide the general guidelines that can promote wetlands, it is often special districts and interest groups that initiate development. A review is also provided in this paper of those agencies and groups that may either actively promote the creation of urban stormwater treatment wetlands or provide additional support for ongoing wetland creation and management activities.

II. COUNTY PLANS

Alameda County

Three elements of the Alameda County General Plan contain policies that support the creation of wetlands: Park and Recreation (8), Conservation (9), and Open Space (10). The use of urban stormwater treatment wetlands is an innovative concept that is not specifically addressed, but application of these wetlands can be seen as a mechanism to accomplish many of the goals and objectives, and rectify some of the problems, identified in the General Plan.

Wetlands obviously hold potential for incorporation in parks, and the Park and Recreation Element promotes the establishment of additional parks. However, a listing of the types of park and recreation facilities to be given consideration in the development of a county-wide system of parks and recreation areas does not specifically list wetlands. Flood control channels and other waterways, scenic areas, bird and game preserves and forest and wildflower reserves are listed, all of which may be interpreted as including wetlands. However, the lack of direct mention of wetlands indicates the generally low priority given to wetland development.

The Conservation Element of the General Plan indicates that a significant water quality problem is pollution from urban stormwater runoff. Stormwater pollution is described as a complex problem with difficult and expensive solutions. Treatment wetlands provide a relatively straightforward, inexpensive means of mitigating this problem not foreseen in the Plan.

The greatest support for wetland development in the Alameda County General Plan is found in the Open Space Element. The ten open space objectives specifically identified have direct applicability to wetlands, although only one makes specific reference to wetlands:

- To provide for the designation, protection, preservation and enhancement of open space on a continuing, permanent basis in Alameda County.
- To relate open space to existing and proposed urban land uses in such a manner as to enhance living conditions in the entire county.
- To indicate areas to be maintained as open space and to relate such areas to open space plans and proposals of adjacent counties and to the region.
- To provide for permanent separation and identification of communities through use of open space that will include park and recreation areas coordinated with a continuous system of trails and scenic tours.
- To provide open space recreation and study areas for the enjoyment and education of all people in the county.
- To provide a continuous system of open space for the preservation, enhancement, and protection of natural scenic features and preservation and protection of watershed and wildlife areas and agricultural areas.
- To preserve and protect the existing bay shoreline by limiting bay fill to public recreation and other selected uses in accordance with adopted regional plans and to protect marine and wildlife habitats by retention of marshlands and water fishery areas.
- To provide a healthful environment and to maintain and improve climate by minimizing air and water pollution, reducing population congestion and traffic congestion by preservation of natural open areas, including San Francisco Bay.
- To assist in stabilizing open space property values and to enhance the urban and rural economy of Alameda County by containing urban growth through the preservation of recreational, agricultural, and other productive open space.

- To provide legal basis for retaining open space through means that will be economically feasible for public and private interests.

Urban stormwater treatment wetlands can retain the values of open space while providing water treatment benefits. Thus, a valuable implementation technique for open space protection is to continue to require adequate provision for the elimination of Bay water pollution. Urban stormwater runoff normally discharges without treatment and is recognized as a significant source of pollutant loading into the Bay. Treatment wetlands should be able to fulfill multiple functions of providing open space and associated wildlife habitat while protecting the Bay from pollution.

Contra Costa County

The development of urban stormwater treatment wetlands is consistent with several goals of the Contra Costa County General Plan. However, these goals are applicable to the development of wetlands in general and are not specific to wetlands treating urban stormwater.

The most significant mention of objectives that would promote stormwater treatment wetlands is the goal expressed in the Open Space and Conservation Plan: "The role of the County now is to make decisions to prevent further degradation of off-shore waters, to protect the tidelands which are vital to commercial and sport fisheries and other wildlife, and to support the efforts of other levels of government to achieve clean water in the future" (11). Policies in the Hydrology and Water Quality section of the Plan also generally support the creation of urban stormwater treatment wetlands: "New developments in the Urban Growth Area should be designed to reduce the volume and velocity of surface runoff and soil erosion." Wetlands receiving runoff from a new development could accomplish this objective and protect downstream areas. Another supporting policy in the Plan provides that "efforts should be made to improve the environmental quality of flood control works and to retain native vegetation to the greatest feasible extent." Flood control basins can be managed as seasonal treatment wetlands without loss of flood control capacity.

Numerous references are made of goals and objectives that support the establishment of wetlands. Specific goals and objectives identified in the Open Space and Conservation Plan include:

- Provide a permanent open space base for the County for a variety of open space uses.

- Plan for resource utilization and development within the framework of a healthy and attractive environment.

- Preserve and enhance historic and scenic features, watersheds, natural waterways, and areas important for the maintenance of natural vegetation and wildlife populations.

- o Provide a well-balanced, well-distributed system of parks and recreation areas.

- o Protect the recreation potential of open space areas and plan for their orderly use and development.

- o Provide connecting links between open space areas.

Specific findings and policies that support these goals and objectives are scattered throughout the Open Space and Conservation Plan. Under the topics of development: "areas which pose a severe risk to life and property should not be developed...these (areas) include...natural waterways and flood prone areas...and areas vital to the preservation of wildlife populations. Areas severely limited in their development capabilities often prove highly valuable for open space uses such as trails, outdoor recreation, keeping livestock for pleasure, and scenic quality." Many of these areas seemingly inappropriate for development could be advantageously used as wetlands.

Under the topic of urban open space, objectives are identified that could be satisfied through wetland creation. A major policy to be met in an urban area is to "utilize open space for public safety and resource conservation for appropriate recreation activities within the framework of providing a variety of recreation opportunities for all segments of the community." Wetlands could also be included in recommended systems to provide "an urban trails system for local use and with connections to the county and regional trails." These objectives may be easily realized using riparian zones and flood plains following natural drainages.

The policies of the Open Space and Conservation Plan regarding vegetation and wildlife generally support wetland development but may discourage the use of wetlands for urban stormwater treatment. The planting of native vegetation is encouraged, in part to provide habitat for native wildlife. A tree ordinance is recommended for the protection of mature trees in developing areas, which could be directly applicable to preserving riparian and flood plain vegetation. However, the major open space use of wetlands is identified as habitat for fish, shellfish and waterfowl, with recreation and commercial uses identified as secondary. No direct mention is made in this context regarding water treatment, but the use of urban stormwater in existing wetlands could come into conflict with wildlife management objectives.

Aesthetic objectives also support the development of wetlands. Recommendations in the Open Space and Conservation Plan are to "locate natural features worthy of special preservation interest" and "find innovative means of acquiring and preserving historic sites and natural features other than outright purchase."

The Parks and Recreation element of the County General Plan also promotes the development of open space that may be conducive to wetland creation (12).

Marin County

The General Plan for Marin County indicates a strong commitment to protect environmental quality (13,14). One of the three basic goals of the Plan is to "achieve high quality in the natural and built environments, through a balanced system of transportation, land use, and open space."

A major section of the General Plan deals with environmental quality, encompassing the requirements for the open space, conservation, seismic safety and recreation elements mandated by the State Planning and Zoning Law.

Marin County established a Environmental Protection Committee to review actions that may "significantly affect the quality of the environment" (13). This committee assumed that "maintaining the present ecological balance and environmental quality is a prime concern...and that the individual who wishes to make a change must demonstrate that the action will not cause severe or irreparable damage." Thus, the burden of proof to show that a project will not cause environmental harm falls upon the developer. In the case of urban stormwater wetland development, it is difficult to determine the ultimate fate of pollutants trapped in the system; some long-term degradation of a wetlands may occur requiring periodic maintenance to minimize environmental harm from pollutants in stormwater. Greater resistance to the use of existing wetlands for stormwater treatment may be anticipated than for new wetland development.

The General Plan designates three conservation zones having specific development restrictions intended to prevent environmental deterioration (14):

1) Stream and Creekside Zones consisting of buffer zones along all natural watercourses. These zones extend to a width of 100 feet outward from the top of the banks in the Coastal Recreation and Inland Rural Corridors and to a width of 50 feet in the City-Centered Corridor.

2) Coastal Zone consisting of the area along the western edge of Marin County extending 1000 yards inland from the shoreline.

3) Bayfront Conservation Zone consisting of three subzones:

   i. Tidal Subzone--including all areas subject to tidal action and all open water. It also includes "all the contiguous and adjacent land up to the line of highest tidal action...; or the landward dike which circumscribes tidal inflow; or the nearest greater than 50% developed urban area; or publicly maintained road; whichever of these bounds the largest area of tidal marsh and channels" (14).

ii. Diked Bay Marshlands Agricultural Subzone--"which includes all historic bay marshlands as determined by Nichols and Wright" (14).

iii. Shoreline Subzone--including a few shoreline areas where main public thoroughfares follow the coastline.

Potential sites for urban stormwater treatment wetlands would frequently be located in these zones, perhaps presenting another obstacle to development. However, a strong case could be made for most treatment wetlands that the project requires this type of location and would enhance environmental quality. While a treatment wetlands should result in improved water quality and lessen the impact of stormwater runoff on fish and aquatic habitats downstream of the site, major alterations could occur to existing wetland habitats. Evaluations would have to be made relating the values of the habitat in existing wetlands with that expected after development as treatment systems. In many cases, a dramatic change in the population structure could be anticipated, particularly if brackish or salt water wetlands were changed to seasonally or permanently fresh.

The Marin County General Plan also designates Stream Conservation Areas. This designation applies to all streams and associated riparian habitats. These areas are generally protected from commercial and structural development. Newly permitted development includes "reconstruction and repairs; necessary water supply projects; flood control projects; developments to improve fish and wildlife habitat; grazing of livestock and other agricultural uses; maintenance of water channels for erosion control and other purposes; road and utility line crossings; water monitoring installations; trails." No mention is specifically made regarding streamside wetlands. However, Stream Conservation Area use in a channel that has been altered for flood control is identified as having "potential urban open space uses as landscaped areas and paths." Developing these areas as wetlands would offer additional benefits including water quality and wildlife habitat enhancement.

A policy for erosion control also promotes treatment wetland development. Surface runoff rates should not ordinarily exceed predevelopment levels. Following typical development, the infiltration capacity of the watershed decreases with a resultant elevation in total and peak stormwater discharge. Routing through a wetlands would attenuate storm flow, protecting downstream areas. Wetlands could also serve as sedimentation basins, now recommended in erosion control policies for use during project construction and as long thereafter as needed.

Several references are made in the General Plan to objectives that could be realized through the use of wetlands. The plan recommends that water pollution be minimized, that a diversity and abundance of wildlife and marine life be maintained, and that adequate parks, recreation facilities and open space be provided. Of particular applicability to the development of urban runoff treatment marshes is that "water supply, flood control, waste water and solid waste disposal, soil conservation, open space preservation and natural resource extraction shall be

coordinated to create the greatest public benefit and the least degree of environmental damage." However, mechanisms to accomplish this coordination are not included in the Plan.

Napa County

Napa County is the least developed of the nine Bay Area counties. Most of the land area in Napa County is currently undeveloped, so many of the policies in the County General Plan call for preservation of existing resources rather than redevelopment (15). The need for open space planning is identified as well as the need to protect valuable watershed and wildlife areas. Protection of these lands is generally to be implemented through density restrictions on areas proposed for development.

Since much of Napa County is undeveloped, little has been done to develop or plan for parks and recreation facilities. The County does not budget for the creation, operation or maintenance of parks or other recreational facilities. The General Plan identifies the need for additional facilities, particularly in support of the tourist industry. The Plan also identifies that open space lands can be managed for multiple uses including recreation. Furthermore, the Plan indicates that recreation in the county is "primarily environmental in nature, requiring very few permanent structures and little development." This type of recreational activity as opposed to these requiring more developed facilities such as golf courses and playing fields, appears very amenable to wetland creation.

San Mateo County

San Mateo County has a combined Conservation and Open Space Element in their General Plan which identifies many environmental concerns that could be accomplished through the use of wetlands (16). However, the Plan emphasizes the preservation of existing wetlands, through a general demand for protecting existing vegetation and wildlife, rather than offering opportunity for wetland development. Some of the protection policies may serve as major obstacles to incorporate water quality treatment as a valuable use of existing wetlands.

The goals and objectives identified for natural vegetative resources and fish and wildlife emphasize the protection and management of natural vegetation and wildlife habitat. Specific reference is made of the need to protect streamside (riparian) zones where fisheries and water quality aspects are important. Wetlands on the Bay are considered areas of primary value; before development is permitted the developer must demonstrate that there will be no significant alteration of the environment.

These general protective policies may be obstacles to the development of treatment wetlands. In primary vegetative resource areas, which would include many of the sites suitable for wetland development, "land uses requiring major modification of the natural vegetation should be prohibited." Appropriate locations for seasonal treatment marsh development would include areas supporting upland vegetation and existing brackish and salt water wetlands. Substantial changes in habitat would occur if these areas were inundated with fresh, stormwater runoff.

While there is considerable mention in the Plan regarding the necessity for maintaining adequate water quality in surface water, ground water and wastewater discharge there is no mention of water quality objectives of runoff into the Bay. Thus, development of an urban stormwater treatment facility would have to be justified primarily on benefits provided by the creation of open space, additional recreational facilities, wildlife habitat and perhaps the most favorable use of unstable lands such as fault zones and flood plains.

Urban stormwater treatment wetlands would fulfill many of the objectives identified in the parks and recreation element of the General Plan (17). This element identifies natural preserves and linear parks and trails as major components of the county park system. Although natural preserves are, by Plan definition, areas to be preserved "in their present state," wetlands could be developed for stormwater treatment to be subsequently included in the preserve system. Linear parks and trails could be created through the use of riparian zones and natural drainages developed into treatment wetlands. Flood control channels have particularly good potential for development as urban stormwater treatment wetlands.

San Francisco

The City and County of San Francisco differs in many respects from other parts of the Bay Area. It predominantly consists of highly developed urban areas, with relatively little potential for restoration of open space areas. Open space and recreational facilities generally do not contain large land areas suitable for development wetlands. Some sites may be available along the coastline and bayshore for wetland development. However, the value of controlling runoff from San Francisco, due to its high level of urbanization, may be greater than for other parts of the Bay Area.

Much of the runoff from San Francisco enters a combined storm-sanitary sewer. Deficiencies in this system are apparent, and San Francisco is currently planning and constructing facilities to better control wastewater and stormwater. Attention is primarily focused on treatment and disposal of wastewater; however, it is important that disposal of stormwater also be considered.

Remaining open space available for development is generally located along some bayshore and coastline areas. Some of these areas may be amenable to the establishment of wetland treatment systems. However, little is mentioned in the General Plan that would support this type of development (18). Stormwater disposal in San Francisco will probably remain integrated in some fashion with wastewater disposal. Land values and availability should prohibit extensive establishment of "natural" treatment systems such as wetlands. The potential for urban stormwater treatment wetlands in San Francisco appears substantially less than for other portions of the Bay Area.

Santa Clara County

Santa Clara County has several policies in their General Plan protecting existing wetlands and some additional policies which may be construed to offer support for wetland development (19). Of particular note is their policy that "the water quality, water surface area and volume, and shoreline development of the whole of San Francisco Bay directly affects and is a part of the environment and public health, safety, welfare, and recreation of Santa Clara County." This policy provides a basis for concern regarding the quality of stormwater runoff as it will affect the entire San Francisco Bay, rather than limiting concerns to those directly affecting only Santa Clara County. The Santa Clara County Baylands Development Policies generally support the preservation of existing baylands, following the basic policies of the San Francisco Bay Conservation and Development Commission.

Many of the policies concerning wildlife and vegetation also support wetland preservation or development. These policies are mainly concerned with the proper management of habitat. Specific reference is made that public agencies in the County should acquire remaining salt water marsh areas; no such provision is made for freshwater marshes. However, a policy regarding wildlife resources recommends that "means should be found to improve water quality in the South Bay below Dumbarton Straits, so that marine fish populations can be reestablished there." This policy may be implemented in part through the treatment of stormwater that carries pollutants into the Bay.

Policies concerning water resources also are supportive of wetland preservation and development. Of particular note is the policy that "studies should be made of the pollution impact of stormwaters to determine if treatment of the waters should be undertaken." Work done by the Association of Bay Area Governments documents the level of pollutant loading into the Bay from runoff and indicates that the level of input from this source is significant (20). However, a case-by-case evaluation of individual stormwater drainages in Santa Clara County has not been done. No provision is made in the General Plan regarding appropriate action if stormwater quality is found to adversely impact San Francisco Bay.

Other water resource policies protect waterways and floodplains, and provide direction for wetland development. Protection of flood plains and maintaining stream quality while enhancing flood protection are complementary goals that could be accomplished through the use of streamside wetlands. Furthermore, the policy to develop the recreation and open space of all water features is consistent with the development of streamside wetlands and/or riparian zones.

The preliminary inventory of natural communities of Santa Clara County presented in the General Plan indicates the general lack of existing freshwater wetland habitat in the County. Only one seasonal marsh was identified, and no streamside marshes, upland alkaline, salt or brackish marshes were found. Some riparian habitat was found in the mountainous areas of the County, as well as one seasonally-wet flood land bordering the Bay. Generally, the creation of seasonal freshwater wetlands would add a type of habitat to the County that would offer greater diversity for wildlife and vegetation establishment.

The Trails and Pathways Master Plan for Santa Clara County has recommendations that publicly-owned lands near creeks be preserved to protect the creekside environment, and that county creekside protective standards serve as a model to guide public and private development near creeks (21). This recommendation could serve to promote streamside wetland and riparian zone development. Trails could be constructed following natural drainages in areas also used as wetland or riparian habitat.

Treatment wetlands may also be developed on areas unsuitable for other development due to the instability of the area. Instability is caused by such factors as seismic activity, flood potential and soil characteristics. Recommendations are given in the Seismic Safety Plan of the County that urbanization of hazardous areas should be discouraged and that the major land use of such areas should be for open space (22). Thus, these areas may be best utilized as wetlands if an adequate seasonal (or perennial) water supply is available.

Solano County

Policies relating to wetlands appear in several elements of the General Plan of Solano County. More consideration of wetlands is included in this General Plan than for the other Bay Area counties. The Suisun Marsh, a large marsh of national significance, is entirely contained within the County. The marsh is protected by the California State Suisun Marsh Preservation Act of 1977 which requires that local policies and regulations conform to the Act (23). The Napa Marsh is partially contained within the County, and also contains large areas of important habitat. While many of the policies in the General Plan were designed to accommodate these wetlands, many of these policies are directly applicable to urban stormwater wetland development. The County Plan also is progressive in recognizing that the control of stormwater quality is an important environmental concern.

The land use and circulation element of the General Plan (24), contains a policy clearly identifying seasonal marshes as a valuable resource:

> In marsh areas, the County shall encourage the formation and retention of parcels of sufficient size to preserve valuable tidal marshes, seasonal marshes, managed wetlands and contiguous grassland areas for the protection of aquatic and wildlife habitat.

This is the only direct reference in any of the county plans to seasonal wetlands. However, the value of using seasonal wetlands in managing stormwater runoff is not identified.

Water quality objectives identified in the Plan recognize the importance of controlling stormwater runoff. Surface runoff management plans have been adopted for both North and South County areas. General policies designed to protect surface water quality are:

- o The County shall ensure that land use activities and development occurs in a manner which minimizes the impact of earth disturbance, erosion and potential surface runoff pollutants on water quality.

- o The County shall preserve the riparian vegetation along significant County waterways in order to maintain water quality.

Flood control policies recognize the value of wetlands (including riparian zones) and call for preservation and protection (25). Specific reference is made that runoff from urban developments "must be accommodated by facilities designed to control the rate and dispersal of runoff." However, no similar need is identified to provide for facilities controlling the quality of runoff. Stormwater treatment wetlands potentially can provide the "quantity and rate" benefits specified in the flood control policies while satisfying water quality objectives.

The Open Space and Conservation Element of the General Plan also provides for the identification of areas that are unsuitable for development (26). Flood plains, airport hazard zones, wildland fire hazard zones and earthquake fault zones may, in some cases, be best used as wetlands. A creekside ordinance is recommended in the General Plan to protect shoreline and backshore areas (27). Preservation of natural riparian habitats would be a major goal of this ordinance. Restoration or development of wetlands bordering drainages may accomplish many of the objectives of this ordinance, although some conflict may result from a change in habitat.

Sonoma County

The General Plan of Sonoma County contains a strong commitment to protect environmental quality (28). Much of the County is currently undeveloped, with only a few major pollution centers. No general policies exist regarding the creation of additional wetlands. However, plans for open space, safety, conservation and water quality all contain elements that could be supported through the development of urban stormwater treatment wetlands.

Water quality policies appear directly applicable to the development of treatment wetlands. Planting of appropriate vegetation on flood control projects is recommended. Vegetated flood control channels, designed and managed properly, can generally be used as a wetland without loss of capacity. Furthermore, policy regarding plant and animal life requires that a system of permanent wildlife habitat areas be established that are representative of Sonoma County floral and faunal communities. Natural freshwater marshes and river courses are specifically mentioned as important habitat types. Estuaries and marshes are further mentioned as important areas of fisheries food production which should be protected.

Several recommendations in the Conservation Element of the General Plan are amenable to wetland development. A riparian ordinance to protect river and stream corridors is recommended. Perhaps more importantly, the multiple use of flood control channels is encouraged. The use of floodplains can provide multiple benefits including water treatment, habitat creation, open space, and recreation. A recreational policy calls for the promotion of natural and man-made streams to provide areas for hiking, biking, and horseback riding. Streamside wetlands can offer these opportunities while retaining other uses of a wetlands.

The Recreation Plan of Solano County identifies the need for additional recreational facilities (27). Specific reference is made in the Open Space and Conservation Element of the Plan to the use of recreation corridors within urban growth centers through "the use of utility rights-of-way, natural watercourses, parks, parkways, water reservoirs and canals, earthquake fault zones and other land areas as appropriate" (28). Wetlands could fulfill these multiple objectives while removing much of the pollutant load associated with runoff from an urban environment.

III. REGIONAL PLANS

The Association of Bay Area Governments (ABAG) functions as a planning agency encompassing the entire Bay Area region. The ABAG Regional Plan (29), incorporating its Environmental Management Plan (30), contains elements important to considerations of wetland creation and restoration. The Regional Plan is developed by "elected representatives of local governments to guide the economic, social and environmental future of the region" (29). Regional planning allows local governments to develop their general plans to be consistent with regional goals and neighboring communities. Many of the county general plans make reference to the ABAG Regional Plan as a guiding document.

Several of the regional goals identified in the Regional Plan support the concept of urban stormwater wetland development:

1. A permanent regional open space system that makes possible the range of activities essential to the city-centered concept of regional development.

2. Protection and enhancement of San Francisco Bay and the major physical features and environmental qualities of the region.

3. Return of the entire Bay Area to a state of ecological well-being.

4. Protection from natural and man-made hazards and disasters.

5. A physical environment pleasing to the senses.

ABAG's Environmental Management Program integrates plans for solving air, water and solid waste problems over the entire Bay region. Thus, environmental planning can be consistent for all types of pollution and effects of a particular action can be viewed with respect to the entire environment. The creation and restoration of stormwater wetlands would serve numerous objectives and needs to be viewed from a wide perspective. The Regional Plan expands upon the Environmental Management Plan providing comprehensive planning for areas other than water, air and solid waste. Specific policies that have application to wetland development in the Regional Plan include:

Water Quality

o Establish a program of surface runoff controls that emphasize low cost measures to reduce the pollutant load from this source.

o Facilitate the re-establishment of recreational and commercial shellfish harvesting in the Bay as allowed by water quality.

Recreation

o Recreation opportunities should be available in or near urban areas.

o Priority should be given to protecting open space within and immediately around urbanized areas.

o Public open space should be secured while it is available.

o The visual quality of the region should be improved.

o The following types of regional parklands should be promoted:

- regional recreation area
- regional park
- regional wilderness
- regional trail
- regional landscape

Critical Areas

o The following wildlife and wildland resources should be preserved:

- land areas associated with fish and wildlife having key roles in a regional scale ecosystem.

- wild lands containing vegetative resources that are elements of an ecological zone of recognized importance or uniqueness; lands whose vegetative qualities contribute to the maintenance of air quality should be identified and protected.

Safety

- Protect floodplains of multijurisdictional rivers and streams

While water, air and solid waste pollution planning have been coordinated, there has been no effort to integrate the elements of safety, critical areas and recreation with water quality to support urban stormwater wetland development. Similar to the county general plans, the major components needed to support wetland activities are identified, but there is no general recognition of the value of wetlands in fulfulling goals from various parts of the Plan.

IV. IMPLEMENTATION

The open space element of each county general plan must contain an action plan to implement the program (31). Since wetlands provide open-space, these implementation techniques are directly applicable to wetland development. Implementation plans are generally insufficient to result, by themselves, in wetland (or other type of open space) development. Implementation planning can be classified into three categories: regulation, management and acquisition. Regulation and management can be effective in preserving existing areas, and on occasion many provide development through the requirement of physical mitigation measures before projects are permitted. Acquisition of lands for wetland development is generally more difficult, and open space elements tend to contain descriptions of how to obtain monies rather than real schedules for acquisition. None of these techniques generally provide for money to develop and manage areas; financial committments only are concerned with land acquisition.

Regulation

Regulatory control is most effective in providing for open space or wetland development when the area is desired for development. Regulation often takes the form of denying development and protecting the existing land use, through reasons such as physical instability (geologic instability, soil unsuitability, flood hazard) public safety (fire hazards, airport zones, transportation corridors), historic preservation, conservation, recreation, habitat protection and scenic travel corridors. Regulatory control commonly takes effect only after a development is proposed, otherwise there is no cause for the area to be modified. There are no provisions in any of the Bay Area county plans that specifically mandate the development of freshwater wetlands, with most protection ordinances designed to affect only existing saltwater wetlands or historic tidelands. However, in granting permits for development, mitigation employing freshwater wetlands might be promoted as an effective means of restoring valuable habitat, providing some control of water quality and quantity, establishing open space and recreational opportunities, and other benefits of a wetland system. The financial obligation to develop wetlands can be made an explicit requirement of the permit granted to the developer. The cost of the wetlands will to some extent be proportional to the size of the intended project, and may in many cases represent only a relatively small fraction of total costs to the developer.

Management

Land management offers the opportunity for wetland development or preservation from many diverse situations. Agricultural areas may provide important crops yet retain considerable value as a seasonal wetland, such as is commonly found in areas devoted to growing rice. While the general plans of the Bay Area counties have references to the values of retaining agricultural areas, their multiple benefits are largely ignored. Similarly, there is a general lack of attention given to the multiple use of other lands. While specific mention is made of areas devoted to open space, open-space access, scenic corridors, riparian protection and areas otherwise unsuitable for development, little mention is made of land types suitable for fulfillment of multiple objectives. Unfortunately, complex multiple-use management, requiring cooperation and coordination from a number of institutions and agencies, is relatively difficult to obtain. The lack of multiple-use planning in general plans or other guiding documents gives no overall incentive for the development of wetlands as a system satisfying multiple objectives. However, multiple-use management may often be the best way to maximize the use of land, and often may be optimized through the establishment of wetlands.

Acquisition

Land acquisition will probably be the cornerstone of any successful system to establish seasonal wetland in the Bay Area. Land may be acquired in several different ways. The simplest way is outright purchase (fee simple). A community, interest group or individual could purchase suitable land and develop it as a wetlands. This acquisition and development would be relatively expensive, and would severely limit the amount of land that might be acquired for wetland development. However, methods are available that can be used to defray some of this cost.

Purchase with leaseback potential can be employed with activities such as farming. Land can be purchased and subsequently leased. A community could thus hold title to the land, and be able to develop it fully as wetlands when its financial situation permits. The lease may be provisional, and require farming of crops such as rice that would result in the current use of the land as a seasonal wetlands.

Land may also be obtained through installment purchase. These installments may take the form of periodic payments with interest, or may not impose interest but delay transfer of title until payments are complete. Installment payments defer some of the cost of the land acquisition, and reserve title to land available for later use.

Specific rights to a property may be acquired rather than obtaining the land itself. An existing wetlands could be retained as a property easement, with the property owner benefitting from tax advantages. Acquiring certain development rights, or the dedication of part of a property may be made a condition of a development permit.

Land may be obtained as a donation. While the donation may be entirely philanthropic, a county can also provide tax incentives. Following the principle of "unlimited deduction", more than the usual tax credit may be given for donations to a public agency. Land may also be given with the provision that the owner be allowed to remain on the property for life. Tax is no longer assessed and full use of the land is deferred until the tenant's death.

Excess condemnation may also provide a useful technique for acquiring land. Extra land can be included when negotiating for a specific public project. Employing this technique allows for the coordination of a specific project with associated projects and land uses.

Many county park districts have responsibility for acquiring lands which may have uses coincident with wetland creation. The park districts generally plan for a gradual acquisition of land, financed from various sources, to achieve the objective of creating adequate parkland to serve their existing and projected populations. A good example of this activity was the tax imposed in 1973 in San Mateo County of 10 cents per $100 of assessed valuation for park and open space acquisition and development purposes. However, the passage of Proposition 13 in 1978 resulted in the loss of ability of the County Park District to impose a tax on property, and funds for acquisition have been sharply reduced. This loss of available revenue for land acquisition following Proposition 13 is common throughout the region.

The East Bay Regional Park District is a special district encompassing parts of both Alameda and Contra Costa Counties. Although their General Plan contains no specific plan for wetland acquisition or development, many of their parks and shorelines now are wetlands or offer the potential for wetland development (32). The Park District, in conjunction with the Association of Bay Area Governments, is currently constructing a seasonal freshwater wetlands at Coyote Hills Regional Park in Fremont. This is the first attempt in the Bay Area to construct a wetland specifically to treat stormwater and act as a prototype system on which to base future wetland design.

V. INTEREST GROUPS

A variety of environmental and other special interest groups may be active participants in wetland creation and restoration activities. These groups generally function as advocates for wetlands through lobbying activities to influence legislation and through support of specific projects. They frequently comment on Environmental Impact Reports and permit applications for proposed projects, and may be instrumental in formulating alternatives and mitigation measures. Environmental groups usually are not able to finance projects directly but may try to arrange for financing from developers, governments, and any other likely source.

Activities in wetlands constitute only a small aspect of the concerns of most environmental groups. The "Wetlands Coalition" was organized by the Save San Francisco Bay Association to provide a forum

and centralized information source for those groups with strong interests in wetlands. The following list of organizations constitute the membership of the "Wetlands Coalition" and provides a good indication of those environmental groups and agencies most actively, or potentially, involved in wetland activities in the Bay Area:

California Trout
People for Open Space
Hercules Environmental Resource Community
California Coastal Wetlands Coalition
Marin Audubon Society
Peninsula Conservation Center
Save San Francisco Bay Association
Coastal Conservancy
Associated Sportsmen
Golden Gate Audubon Society
Committee for Green Foothills
Ohlone Audubon Society
Santa Clara Audubon Society
Sequoia Audubon Society
California Tomorrow
Sierra Club, Bay Chapter
Friends of the Earth
Marin Conservation League
Oceanic Society
California Waterfowl Association
Environmental Defense Fund
State Lands Commission
Sierra Club, Loma Prieta Chapter
Tri-City Ecology Center
San Francisco Bay Conservation and Development Commission
United States Fish and Wildlife Service

A few groups have some capability for limited financing of wetlands projects. For example, the National Audubon Society occassionally is able to assume responsibility for management and operations of a wetlands, reducing the long-term financial committment needed to implement wetland development (33). It also can serve to survey wetland conditions and monitor the success of wildlife population becoming established in the area.

Hunting clubs may also offer some opportunity for financing wetland activities. These clubs have a history of purchasing land and maintaining it as wetlands. While hunting interests are sometimes incompatible with other uses, runoff treatment could be effectively accomplished in a wetlands used extensively for hunting. However, the location of treatment wetlands near urban settings may effectively eliminate hunting as a primary use, and exclude these wetlands from hunting club consideration.

The Trust for Public Lands offers a somewhat different approach toward wetland acquisition (34,35). It acquires open space in private ownership and arranges for transfer of title to public agencies. The Trust generally acquires land as a gift or at a below market price, with the land owner obtaining tax benefits. The Trust can then give or sell this land at a low price to public agencies. Lands may also be retained

by the Trust until such time as a developer needs to obtain land for mitigation. The developer can purchase an equal value of land from the Trust to give to the State Lands Commission in return for the removal of public trust interests over the proposed development site.

The Trust for Public Lands offers a innovative mechanism for preserving existing wetlands and acquiring lands for wetland restoration. However, the Trust does not provide monies for developing or managing wetlands. To effectively implement wetland development programs, actions must include commitments from other groups or agencies.

IV. SUMMARY

The preservation, restoration and development of wetlands are nominal goals common to local and regional governments. Unfortunately, it is often difficult to ascertain the strength of their commitment. Establishing seasonal treatment wetlands utilizing runoff as the prime water supply is an innovative concept that has not been incorporated into general planning activities. While local governments recognize the value of wildlife habitat, open space, recreational opportunities, and other features offered by a wetland, there appears to be less local commitment toward the overall water quality of the Bay. Thus, a treatment wetlands, to be successfully established, would probably have to be promoted on the basis of its multiple use functions.

Implementation of plans recognizing wetland establishment as a means of fulfilling multiple objectives is often difficult. Financial mechanisms for acquiring, developing and maintaining wetlands are limited, and general plans do not offer schedules for obtaining funds. At worst, general plans may simply be identifying many of the values associated with wetlands, with no real attempt being made to accomplish these goals. However, the recognition of the values of wetlands coincident with local government goals offers the opportunity for interest groups to strongly promote establishment or preservation of wetlands within an existing government framework.

Numerous interest groups will work for wetland preservation and development. These groups can be a strong force encouraging efforts at all levels of governments. Interest groups can play a valuable role in offering measures to mitigate possible adverse affects of development. Interest groups can be particularly effective in monitoring and evaluating a site to determine both possible impacts of development and the success of mitigation measures.

Wetlands offer a great diversity of values, leading to a broad spectrum of individuals, interest groups and agencies with concerns and control over wetland preservation, restoration and development. To successfully implement a wetlands plan, coordinated efforts will have to take place recognizing diverse interests. The main participants in wetland activities have been identified in this, and the preceding, Technical Memorandum (3). It will be through the commitment and effectiveness of these participants that decide the ultimate health and extent of Bay Area wetlands.

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W.Q. Tech. Memo No. 90
Emy Chan

REGIONAL WETLANDS PROGRAM FOR URBAN RUNOFF TREATMENT

INVENTORY OF POTENTIAL SITES FOR THE CREATION OF URBAN RUNOFF TREATMENT SYSTEMS

Technical Memorandum No. 90
December 2, 1982

INTRODUCTION

This memorandum is a working paper for the Regional Wetlands Program for Urban Runoff Treatment. The purpose of the plan is to encourage local entities to utilize wetland treatment systems, where feasible, for the cleansing of pollutants from surface runoff waters. In this way, not only are surface and ultimately Bay water quality improved, but multiple benefits are also reaped from the improvement of ecological and recreational resources.

The purpose of this paper is to present the criteria used for preliminary site evaluation and selection, and to present an initial inventory and mapping of potential sites for wetlands restoration or creation in the Bay Area. The sites are not field verified and site identification in this paper does not constitute an endorsement for wetland restoration, Rather, site mapping should be used as a guide for physical suitability; however, implementation would be strictly voluntary.

Background

The ABAG Environmental Management Plan, adopted in 1977, recognized that urban lands draining into San Francisco Bay can contribute significant amounts of pollutants to the surface runoff. These pollutants, such as suspended solids, organic debris, nutrients, dissolved heavy metals and hydrocarbons, can be detrimental to local stream systems and ultimately the Bay ecosystem as well. Local communities are beginning to comprehend these problems and are interested in low-cost solutions that are effective and can provide multiple benefits.

One of the most promising low-cost treatment solutions researched by ABAG during 1980-81 was the use of wetland systems to process surface runoff waters. In the report "The Use of Wetlands for Water Pollution Control" (Chan et al., 1981), various types of wetlands--ranging from fresh to salt water marshes--were found to be able to absorb, breakdown or store many pollutants commonly found in wastewater and surface runoff water.

Artificially-created wetlands could be as effective as natural wetland systems and, in many cases, the total costs for this type of system would be competitive with conventional public-works type treatment systems. In addition, wetlands could yield multiple benefits to a local community through the provision of wildlife habitat, recreational use, open space and buffers against future urban development. As local interest in wetland treatment systems began to swell, the need for information on potential sites for wetlands creation/restoration, development criteria and methods for implementation became apparent.

The 1981-82 ABAG Water Quality Management Program features the preparation of a Regional Wetlands Plan for Urban Runoff Treatment, which would give guidance to local communities on selection of wetland sites, design criteria, approximate costs, operation methods and alternative uses. Implementation of this type of alternative treatment system could not only result in cost and energy savings to local communities, but could also improve Bay water quality and increase the amount of critical fresh and brackish water wetland habitats in San Francisco Bay.

Information Sources

Information for this Tech. Memo. was compiled from the following sources:

1. U.S.G.S. Quadrangle Topographic (Quad) Maps for the San Francisco Bay Area (1978-81).

2. U.S. Department of the Interior, National Wildlife Inventory (as mapped on U.S.G.S. Quad. maps).

3. "Protection and Restoration of San Francisco Bay Fish and Wildlife Habitat, Volumes I and II," U.S. Fish and Wildlife Service and California Department of Fish and Game, 1979.

4. California State Automobile Association, Road Guides for the San Francisco Bay Area.

CRITERIA FOR SITE SELECTION

The following parameters were evaluated in a preliminary review of potential sites. All parameters were chosen to conform to mapping on U.S.G.S. 7-1/2' quadrangles of the Bay Area.

Available Water Supply

The formation of a freshwater marsh system requires a reliable source of water during all or at least part of the year. Conditions on a U.S.G.S. quad map indicating possible water sources for a wetlands are:

1. Perennial watercourse (solid blue line);

2. Intermittent watercourse--flows seasonally (dashed blue line);

3. Ephemeral drainage course--not shown on quads, but often indicated by land contour lines as a drainage swale or path;

4. High groundwater table--not shown on quads; but often can be inferred by the presence of marsh symbols in flat areas indicating saturated ground conditions.

Urban Drainage Area

Wetland systems can accommodate a variety of water quality conditions ranging from high sediment loads in rural runoff to high organic and nutrient loads in vegetated areas to combinations of sediment and dissolved materials in urban runoff.

For this mapping inventory, the opportunity to treat urban runoff has been emphasized, although this does not exclude a site from receiving rural runoff, groundwater flows, tidal inflows or other water sources. An urban area of 25 acres, roughly corresponding to 100 homes on .25 acre lots, was selected as the minimum urban drainage unit for this study. The most current U.S.G.S. quad. maps for the Bay Area (either photorevised or photoinspected in 1978-80) were used to delineate urban areas. Urban areas were defined as combinations of one or more of the following land uses:

1. Residential
2. Commercial/Services
3. Industrial/Manufacturing
4. Transportation/Communications/Utilities
5. Military/Institutional

Minimum Site Size

The smallest size wetland that can survive and maintain its integrity varies with the water availability and local conditions. Small marshes of less than 1 acre in size or linear marshes less than 100-feet wide along water courses have been observed in the Bay Area. Marshes could develop in small land pockets and virtually along any water body. However, the use of wetlands as a tool for processing urban runoff in the Bay Area implies either a large extent of wetlands or many wetlands parcels scattered along the lower fringes of urban areas.

For ease of visibility in mapping, the smallest mapping unit was chosen to be 5 acres--which roughly corresponded to a 1/4-inch square on a U.S.G.S. 7-1/2' quad. Sites smaller than 5 acres would probably be abundant, however, the precision of locating these sites would be tenuous since the quads often do not show small streets, major land developments such as parks, shopping centers and industrial areas, or the most recent (post 1978) land developments. The other criteria for

site selection nevertheless are applicable (particularly water availability) and development of small sites less than 5 acres will be addressed in the Regional Wetlands Plan.

Compatible Topography

One of the most obvious characteristics of wetlands are their tendency to form in "sinks" or low-lying areas. Thus, wetland formation requires shallow-to-deep land depressions and, if peripheral marshes are desired around an open water body, then shallow areas where the water would be less than 3-ft deep are necessary.

If a wetland is to be artificially created on a site, then earthwork such as grading of shallow and deep areas, islands, drainage channels and berms may be employed. In this case, the absolute flatness of the land is not a requirement, since the amount of cut and fill in the landscape design can compensate for topographical irregularities. Nevertheless changes in major topographical features such as mounds, hills and ridges can be costly and may render a site unfeasible for wetland creation.

Compatible Land Use

The site should also be relatively open and undeveloped. Removal of large structures and trees, if there are many, can complicate construction activities. The proximity to the site of urban land uses does not necessarily preclude a marsh project. On the contrary, a wetland may provide an open space buffer, diversify land use and increase land values in areas used by the public. Types of existing land use that would be compatible with wetlands creation are:

1. Existing wetlands--particularly seasonal wetlands and areas with degraded habitats.

2. Pasture lands

3. Agricultural lands (excluding orchards)

4. Ruderal areas--disturbed and waste areas (such as road sides), abandoned pasture and agricultural lands with weedy vegetation

5. Barren--waste areas with little or no vegetation

6. Marginal or interior areas with one or more of the above uses that exist within other land uses such as residential, commercial, industrial, utilities or "upland" areas.

Proximity to Historic Marsh Boundary

The historic marsh boundary of San Francisco Bay has been researched and mapped by Nichols and Wright on U.S.G.S. quads. In general, this boundary has been mapped at the 5-ft contour. This land elevation is about 3-ft above mean high water (MHW) and approximates the upper edge of tidal marshes (Harvey et al., 1978). If tidal flow were restored to many presently diked shoreline areas, tidal marshes could become reestablished up to this elevation.

Potential sites for tidal marsh restoration and protection were studied very intensively by the Bay Conservation and Development Commission (BCDC) in their recent "Diked Historic Baylands Study". The limit of the BCDC study was diked areas within the historic marsh boundary or diked areas below the 5-ft contour. Within the diked bayland sites, BCDC identified not only potential salt marsh sites but also areas with fresh and brackish water marshes. The majority of these sites, particularly those closer to upland areas, were either presently receiving surface runoff or could be adapted to receive surface runoff. As the BCDC study comprehensively identified marsh restoration sites below 5-ft, the diked historic baylands were not reevaluated for this inventory. However, sites within the historic baylands, as identified by BCDC, are included in this mapping to indicate potential marsh restoration sites.

Above the 5-ft elevation, marsh restoration/creation sites would probably support fresh-to-brackish water marshes depending on local conditions. Since bayland areas below 5-ft have been extensively evaluated, this mapping effort focuses on areas above the historic marsh boundary and above 5-ft in elevation. However, non-diked historic bayland sites--not included in the BCDC study are also evaluated here. Since most of the established urban areas are densely developed, the remaining marsh restoration sites tend to be concentrated along the urban fringe just above the historic marsh margin.

REGIONAL MAP OF POTENTIAL SITES FOR THE CREATION OF URBAN RUNOFF TREATMENT WETLANDS

Base Maps

The mapping of potential marsh restoration sites focused on the quads covering the baylands--which coincided with the major urban runoff receiving areas. Since many of the sites identified in the BCDC "Diked Historic Baylands Study" fit within the selection criteria for this study, the same base maps utilized by BCDC were incorporated into this mapping effort. Thus, the ABAG sites--generally above 5-ft in elevation, are juxtaposed with the BCDC sites--which are below 5-ft in elevation, facilitating comparison on the same scale. Quad maps of areas further inland were either densely urbanized--yielding few sites, or had insufficient or not up-to-date detail on urban areas. Potential wetland creation sites other than those identified in this study will be addressed in the general criteria description section of the Regional Wetlands Plan.

Site Mapping

Based on the selection criteria presented in the previous section, potential sites for the creation of urban runoff treatment systems were evaluated and mapped. An inventory of these selected sites, their approximate size (to the nearest 5 acres) and existing habitat is compiled in Appendix A. The locations of these sites within the Bay Area are presented in a series of regional maps in Appendix B. Table 1 presents a summary of the potential sites by county.

Limitations on Map Interpretation

The potential sites were chosen primarily on the basis of physical suitability from the examination of U.S.G.S. quads and habitat inventory maps. The number, size and location of sites within any given locale do not represent an actual requirement for wetlands restoration or creation. The determination of wetland area and type of habitat needed for this type of treatment system would be dependent upon watershed conditions, local water quality, site conditions, site availability and local support or opposition. The sites presented in Appendix B are based on preliminary staff evaluations and are not field verified. This information is intended to serve as a guide for the types of land that could be available for future in-depth considerations. Wetlands development at these sites would be voluntary.

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TABLE 1. **SUMMARY OF POTENTIAL BAY AREA URBAN RUNOFF TREATMENT SITES**

County	Locale and No of Sites	Approximate Size (acres)	Site Designation*
Alameda	Albany (1)	5	AAL 1
	Emeryville (1)	30	AAL 2
	San Leandro (1)	30	AAL 3
	San Lorenzo (5)	185	AAL 4 - 8
	Union City (6)	515	AAL 9 - 14
	Newark (5)	280	AAL 19 - 24
	Fremont (14)	2385	AAL 15 - 18 and AAL 24 - 33
Contra Costa	Richmond (10)	310	ACC 1 - 10
	Hercules (2)	50	ACC 11 - 12
	Rodeo (1)	10	ACC 13
	Martinez (3)	75	ACC 14 - 16
	Pacheco (1)	30	ACC 17
	Port Chicago (3)	31	ACC 18 - 20
	West Pittsburg (7)	116	ACC 21 - 27
	Pittsburg (5)	55	ACC 28 - 32
Marin	Novato (2)	65	AMR 1 - 2
	Hamilton AFB (2)	26	AMR 3 - 4
	Marinwood (1)	150	AMR 5
	San Rafael (4)	145	AMR 6 - 9
	Larkspur (1)	20	AMR 10
	Corte Madera (2)	60	AMR 11 - 12
	Mill Valley (1)	20	AMR 13
	Marin City (1)	35	AMR 14
	Belvedere (1)	10	AMR 15
Napa	Napa (17)	680	ANA - 17
San Francisco	San Francisco (29)	22	ASF 1 - 2
Santa Clara	Palo Alto (1)	60	ASC 1
	Mountain View (3)	450	ASC 2 - 4
	Sunnyvale (5)	180	ASC 5 - 9
	Santa Clara (3)	300	ASC 10 - 12
	Alviso (2)	190	ASC 13 - 14
	Milpitas (10)	480	ASC 15 - 24
	San Jose (1)	25	ASC 25
San Mateo	Brisbane (1)	5	ASM 1
	South San Francisco (4)	49	ASM 2 - 5
	San Mateo (2)	17	ASM 6 - 7
	Foster City (1)	25	ASM 8
	Belmont (1)	25	ASM 9
	Redwood City (3)	43	ASM 10 - 12
	East Palo Alto (2)	50	ASM 13 - 14

County	Locale and No of Sites	Approximate Size (acres)	Site Designation*
Solano	Vallejo (4)	90	ASL 1 - 4
	Benicia (2)	100	ASL 5 - 6
Sonoma	Petaluma (2)	110	ASN 1 - 2
All Counties Total (146)		7739	

*For identification of site designations, refer to Appendix A, for location of designated sites, refer to Appendix B.

APPENDIX A. INVENTORY OF POTENTIAL BAY AREA URBAN RUNOFF WETLAND TREATMENT SITES

Site No.	Location	Approximate Size (acres)	Use/Habitat**
ALAMEDA COUNTY			
AAL-1	Albany: E. of Hwy. 80. Along S.P. Railroad tracks at Codornices Creek.	<5	Upland
AAL-2	Emeryville: N & W of Hwy. 17 & 80.	<30	Salt marsh (E2EMN2)
AAL-3	San Leandro: SE of airport runways, NW of Airport Dr., W of Earhart Rd.	<30	Freshwater marsh (PEMW)*; recreational area/park (ARP)
AAL-4	San Lorenzo: S of Lewelling Blvd., N of San Lorenzo Creek, W of railroad tracks.	<50	Barren (A/EBR)
AAL-5	San Lorenzo: N of Grant Ave., W of Railroad Ave., adjacent to Tutchins Dr.	50	Freshwater marsh (PEMY)*; barren (A/EBR & A/ERV)
AAL-6	San Lorenzo: W of Via Harriet, W of railroad tracks., at W end of Keller Ave.	10	Recreational area/park (ARP)
AAL-7	San Lorenzo: N of Sulphur Ck., W of railroad tracks, W of Hayward Air Terminal.	25	Barren (A/ERV), freshwater marsh (PEMW)* 5%
AAL-8	San Lorenzo: S of Sulphur Ck., W of railroad tracks, N of Winton Ave., W of Hayward Air Terminal.	50	Barren (A/ERV)
AAL-9	Union City/Alvarado: Adj. and W of Union City Blvd., N of Alameda Ck., and E of S.P. Railroad.	75	Row crops/orchard (ARO), pasture (APF) 8%
AAL-10	Union City/Alvarado: W of S.P. Railroad and Alameda Ck., W of Union City Rd.	100	Row crops/orchard (ARO)
AAL-11	Union City/Alvarado: W of S.P. Railroad and Alameda Ck., W of Union City Blvd.	25	Shallow water (EG1h)
AAL-12	Union City: W of Union City Blvd., S of Benson Rd.	175	Freshwater marsh (PEMY)* 15%, pasture (APF), salt marsh (E2EM7C1/2h)

Site No.	Location	Approximate Size (acres)	Use/Habitat**
AAL-13	Union City: W of Union City Blvd. around Hall Ranch Park	100	Freshwater marsh (PEMW)*15%, freshwater pond (POWFØ), pasture (E2APh)
AAL-14+	Union City: Adjacent to Sanderling Dr. and flood control channel	40	Upland
AAL-15	Fremont: Coyote Hills, N of Park, SW of Newark Blvd.,N of Ditch	125	Pasture (APF), seasonal fresh-water marsh (PSSY)*
AAL-16	Fremont: Coyote Hills Regional Park	40	Freshwater marsh (PEMY)*60%, pasture (APF)
AAl-17	Fremont: Coyote Hills Regional Park., SW of Newark Blvd.	750	Pasture (APF), agriculture (AAO)
AAL-18	Fremont: Coyote Hills Regional Park, NE of Newark Blvd.	625	Pasture (APF), agriculture (AAO)
AAL-19	Newark: N of Thornton Ave., W of Jarvis Ave., E of Overlake Ave.	30	Freshwater marsh (PEMW)*, salt marsh (E2EM7Cl/2h), pasture (AP)
AAL-20	Newark: N of Perrin Ave., W of Willow Rd., S of Wells Ave.	40	Freshwater marsh (PEMW)* 30%, ruderal (A/ERV)
AAL-21	Newark: SE of Mowry Ave., along Station Rd. and Addition Rd.	90	Agriculture, pasture (AP)
AAL-22	Newark: SE of Mowry Ave., E of Mowry Slough, SW of railroad	40	Industrial (UIM)
AAL-23	Newark: SW of Mowry Ave., E of Mowry Slough, SW of railroad	70	Freshwater marsh (PEMW)* 50%, ruderal (A/ERV), pasture (APF)
AAL-24+	Fremont: Miles Community Park, N and adjacent to Alameda Ck.	40	Recreational area/park, fresh-water lake
AAL-25+	Fremont: Irvington District, High St., Grimmer Blvd.	20	Urban?
AAL-26+	Fremont: N of Grimmer Blvd., adjacent to Technology Dr. and Solar Way	90	Industrial?

Site No.	Location	Approximate Size (acres)	Use/Habitat**
AAL-27+	Fremont. S of Grimmer Blvd., adjacent to Enterprise St.	35	Industrial
AAL-28	S. Fremont: W of Fremont Raceways, E of S.P. Railroad, N of Cushing Rd.	250	Freshwater marsh (PFLW, PEMW, PEMY)* pasture (AP & AF), freshwater pond (POWFØ)
AAL-29	S. Fremont: W of Hwy. 17, W & S of and adjacent to Cushing Rd.	70	Salt marsh (E2EMP)*, pasture (AP), barren (A/EBR)
AAL-30	S. Fremont: N of Warren Rd., W of Hwy. 17, W of Landing Rd., S of Cushing Rd.	40	Adjacent to salt marsh (E2EMN), pasture (APF)
AAL-31	S. Fremont: N of Warren Rd., W of Hwy. 17, E of Landing Rd.	75	Pasture (APF)
AAL-32	S. Fremont: S of W. Warren Ave., W of Hwy. 17	125	Adjacent to freshwater marsh (PEMY), ruderal (A/ERV)
AAL-33+	S. Fremont: N of Scott Ck. Rd., W of S.P. Railroad, E of Hwy. 17, S of Warren Ave.	100	Row crops and orchard (ARO)
CONTRA COSTA COUNTY			
ACC-1	Richmond: Point Isabel area, S of intersection of Central Ave. & Rydin Rd., W of Hwy. 17	<10	Freshwater marsh (PEMY) 25%, ruderal (A/ERV)
ACC-2	Richmond: W of Hwy. 17, S of Seaport Ave. between 49th and 51st Sts.	<5	Freshwater pond (POWKZ), diked salt marsh (E2EM7C1/2h), industrial (UIM)
ACC-3	Richmond: S of Hwy. 17, S of Griffin Ave., E of Butler & S 27th St.	<5	N of freshwater marsh (PEMY)*, ruderal (A/ERV)
ACC-4	Richmond: SW of Hwy. 17, SE of intersection of Seaver Ave. & S 34th St.	10	Ruderal (A/ERV)
ACC-5	Richmond: West of 13th St., N of Lincoln, S of Sanford Ave., NE of intersection of Hensley & Kelsey Sts., surrounded by railroad tracks.	10	Upland

Site No.	Location	Approximate Size (acres)	Use/Habitat **
ACC-6	N. Richmond: N of Gertrude, W of York St.	25	Industrial (UIM), commercial (UCS), ruderal (URV)
ACC-7	N. Richmond: E of Garden Tract Rd. at end of DeCarlo Ave.	45	Industrial (UIM), pasture (AF) 10%
ACC-8	N. Richmond: E of Garden Tract Rd., S of Parr Blvd., N of Pittsburg Ave.	45	Ruderal (URV), pasture (AF)
ACC-9	N. Richmond: East of Goodrick Ave., from Parr Blvd., N to Banks Dr., W of Jenkins Way	<125	Freshwater marsh (PEMY)* 10%, ruderal (URV), barren (A/ERV)
ACC-10	N. Richmond: East of site ACC-9, W of Giant Hwy., S of Morton Ave.	30	Barren (A/ERV)
ACC-11	Hercules: N of San Pablo Ave., W of Hercules Ave., SE of Railroad Ave. (on Pinole Creek)	30	Pasture (E2APh/E2AFh), ruderal (URV)
ACC-12+	Hercules: E of Hwy. 80, N of Refugio Valley Rd., S of Redwood Rd. (on Refugio Creek)	20	Adjacent to Refugio Valley Park
ACC-13	Rodeo: W of Hwy. 80, E of and adjacent to Willow Ave. between Hawthorne Dr. & Thomas Ct.	10	Along Rodeo Creek, unknown
ACC-14	Martinez: Martinez Regional Shoreline, N of Marina Vista, W of North Court St.	25	Salt marsh (E2EMN2), industrial (UIM)
ACC-15	Martinez: Martinez Regional Shoreline, N of Marina Vista, W of North Court St.	<25	Salt marsh (E2EMN7C1/2h), barren (A/ERV)
ACC-16	Martinez: Martinez Regional Shoreline, N of Marina Vista, E of North Court St.	25	Recreation area/park (ARP), barren (A/EBR)

Site No.	Location	Approximate Size (acres)	Use/Habitat **
ACC-17	Pacheco: N of Hwy. 4, E of Blum Rd., W of Solano Way, along Pacheco Creek	30	Freshwater marsh (PEMY)*60%, freshwater pond (POWKZ)* 40%, industrial (UIM), pasture (AP)
ACC-18	Port Chicago: N of Waterfront Rd. in U.S. Naval Magazine	15	Freshwater marsh (PEMW),* military (UMI)
ACC-19	Port Chicago: S of Waterfront Rd., W of Main St., N of Port Chicago Hwy., adjacent to Belloma Slough	6	Freshwater marsh (PEMY),* diked brackish water pond (E2OWV3h)
ACC-20	Port Chicago: E of Main St., Waterfront Rd. intersection, N of Port Chicago Hwy.	10	Freshwater marsh (PEMY)*, pasture (AF)
ACC-21	E. Contra Costa Co.: N of Port Chicago Hwy., N of intersection of Driftwood Dr. and Port Chicago Hwy., S of railroad tracks	10	Pasture (AP)
ACC-22	E. Contra Costa Co.: E of Port Chicago Hwy., N of Sharon Dr., S of and adjacent to railroad tracks	10	Pasture (AP)
ACC-23	W. Pittsburg: N of Willow Pass Rd., W of N. Broadway, E of Pamela Dr., S and adjacent to railroad tracks, NW of oil refinery	10	Industrial (UIM)
ACC-24	W. Pittsburg: N of site ACC-23 on N side of railroad tracks	30	Pasture (AF), brackish marsh (E2EM4/57N3)
ACC-25	W. Pittsburg: N of Willow Pass Rd., between Fairview Dr. and Crivello Ave., encircled by railroad tracks	16	Pasture (AP)
ACC-26	W. Pittsburg: N of Willow Pass Rd., N of railroad tracks and west and adjacent to W.P. railroad	20	Pasture (AP)
ACC-27	W. Pittsburg: Across Willow Pass Rd. from site 26. S and E of Willow Pass Rd., N of railroad tracks	20	Pasture (AP)

Site No.	Location	Approximate Size (acres)	Use/Habitat**
ACC-28	Pittsburg: S of N. Parkside Dr., W of Andrew Ave. and NW of end of W. 17th Street	5	Pasture (AP), freshwater pond (POWZ)*
ACC-29	Pittsburg: S of Willow Pass Rd., W of Beacon St., N of railroad tracks	15	Pasture (AF)
ACC-30	Pittsburg: W of Montezuma St., next to Sacramento River, adjacent to sewage treatment plant. Riverview Park	15	Industrial (UIM)
ACC-31	Pittsburg: Between Marina Blvd. and Pittsburg Marina, Central Basin, N of E. 3rd, S of Cutter St.	10	Ruderal (A/ERV)
ACC-32	Pittsburg: E of Harbor St., S of Industry Rd., N of Santa Fe Ave.	10	Ruderal (A/ERV)
MARIN COUNTY			
AMR-1	Novato: N of Novato Ck. between Hwy. 101 and NWPRR tracks	40	Pasture
AMR-2	Novato: S of Novato Ck., W of Hwy. 101, E of Redwood Blvd.	5	Pasture
AMR-3	Hamilton AFB: S of Ignacio, E of NW Railroad at end of Skeet Range Rd.	10	Seasonal freshwater marsh (PSSY)*, ruderal (A/ERV)
AMR-4	Hamilton AFB: S of Ignacio, N of State Access Rd., S of Skeet Range Rd.	16	Urban
AMR-5	Marinwood: E of Hwy. 101, S of St. Vincent Dr., W of railroad tracks (Miller Creek)	150	Freshwater marsh*(PEMW) $<10\%$, pasture (AP)

Site No.	Location	Approximate Size (acres)	Use/Habitat**
AMR-6	San Rafael: E of Hwy. 101, E of Civic Center Dr., N of Marin Civic Center	100	Adjacent to subtidal flats (E1OWL)*, ruderal (A/ERV)
AMR-7	San Rafael: NW of intersection of Main Dr. and Pt. San Pedro Rd.	15	Intertidal mudflat (E2FL3N), ruderal (A/ERV)
AMR-8	San Rafael: Albert Park, W of Lindaro St., S and adjacent to railroad tracks	5	Urban
AMR-9	San Rafael: S of Hwy. 101, N and adjacent to Anderson Dr.	25	Ruderal (A/ERV)
AMR-10	Larkspur: N of Magnolia Dr., NW of Bon Air Rd.	20	Ruderal (A/ERV), <10% (PEMW)*
AMR-11	Corte Madera: Town Park, N of Tamalpais Dr., E of Pixley Ave.	25	Freshwater pond (POWZ, POWKZ)*
AMR-12	Corte Madera: S of Paradise Dr., E of Hwy. 101, W of railroad	35	Urban
AMR-13	Mill Valley: S of Miller Ave., N of Almonte Blvd., E of Gomez Way	20	Residential (URH)
AMR-14	Marin City: N of Hwy. 1, adjacent to Bay, W of Hwy. 101 (Coyote Creek)	35	Salt marsh (E2EMN2), commercial (UCS)
AMR-15	Belvedere: N of Tiburon Blvd., S of Mar West St.	10	Freshwater marsh (PEMY)*, diked salt marsh (E2EM7C1/2h)
<u>NAPA COUNTY</u>			
ANA-1	Napa: S of Salvador Ave., E of Plaso Dr.	8	Upland
ANA-2	Napa: S of El Centro Ave., N of Trower Ave., E of Glacier Dr.	15	Agriculture

Site No.	Location	Approximate Size (acres)	Use/Habitat**
ANA-3	Napa: N of Trancas St., E of Willis Dr., S of Garfield Lane	30	Upland
ANA-4	Napa: N of Trancas St., E of Big Ranch Rd., adjacent Napa River	10	Upland
ANA-5	Napa: S of Trancas St., between Milliken Ck. and Napa River	90	Agriculture
ANA-6	Napa: N of Lincoln Ave., W of Napa River., adjacent to Shoreline Dr. and Stonehouse Dr.	50	Upland
ANA-7	Napa: E of Soscol Ave., NE of McKinstry, S of Imperial Lane, W of Napa River	10	Urban
ANA-8	Napa: N of 1st St., SW of Napa River, E of McKinstry St.	10	Urban
ANA-9	Napa: S of 1st St., W of Napa River, E of Soscol Ave.	10	Urban
ANA-10	Napa: S of Browns Valley Rd., near McCormick Lane, N of Napa Creek	6	Agriculture
ANA-11	Napa: N of 1st St., E of Matt Dr., S of Napa Creek	10	Urban
ANA-12	Napa: N of 1st St., S of Napa Creek, adjacent and east of Hwy. 29	12	Urban
ANA-13	Napa: N of Hwy. 29, 12, 121, SW of Soscol Ave., E of Napa River, adjacent to railroad tracks	70	Pasture (APF)
ANA-14	Napa: S of River Park Blvd., adjacent and W of Napa River	60	Pasture (E2APh)

Site No.	Location	Approximate Size (acres)	Use/Habitat**
ANA-15	Napa: E of Hwy. 12 and 121, S of Sheveland	100	Pasture (AP)
ANA-16	Napa: S of John F. Kennedy Park, E of Napa River, W of Railroad	90	Recreation (ARP)
ANA-17	W of Sonoma Blvd., NW of Sears Pt. Rd., adjacent to Napa River	100	Salt marsh (E2EMP)
<u>SAN FRANCISCO</u>			
ASF-1	San Francisco: N of Candlestick Park and Hunters Pt. Expwy., E of Fitch St.	12	Barren (A/EBR)
ASF-2	San Francisco: Candlestick Park, S of Hunters Pt. Expwy.	10	Recreation area (ARP)
<u>SAN MATEO COUNTY</u>			
ASM-1	Brisbane: N of Main St., between Bayshore Blvd. and PG&E transmission lines	5	Freshwater marsh (PEMW)* $<$20%, urban
ASM-2 +	S. San Francisco: W of Mission Rd. between Oak Ave. and Chestnut Ave. (Colma Creek)	10	Adjacent to freshwater marsh (PEMY)*, urban
ASM-3 +	S. San Francisco: N Canal St., at Spruce Ave. (Colma Creek)	8	Adjacent to tidal creek (E1OWL)*, urban
ASM-4	S. San Francisco: E of Hwy. 101, on E Grand Ave. between Sylvester Rd. and S.P. railroad tracks (Colma Creek)	15	Freshwater marsh (PEMY)* $<$10%, industrial (UIM)
ASM-5	S. San Francisco: E of Hwy. 101 between Hwy. 380 interchange and Marco Way	16	Adjacent to tidal creek (E1OWL)*, barren (A/EBR)
ASM-6	San Mateo: S of E. 3rd Ave., NE of Norfolk St., N of Shoreview Ave.	5	Freshwater marsh (PEMY) $<$ 50%, ruderal (A/ERV)
ASM-7	San Mateo: N of Kehoe Ave., adjacent to sewage treatment works, E of Shoreview Ave.	12	Residential (URH)

Site No.	Location	Approximate Size (acres)	Use/Habitat**
ASM-8	Foster City: N of Hwy. 92, W of Foster City Blvd.	25	Commercial (UCS), fresh-water marsh (PEMW)*20%
ASM-9	Belmont: W of Hwy. 101, E of Industrial Way, S of Harbor Blvd.	25	Industrial (UIM)
ASM-10	Redwood City: S of Bair Is. Rd., NW of Redwood Creek, N of Hwy. 101	20	Freshwater marsh (PEMW)*; barren (A/EBR)
ASM-11	Redwood City: N of Hwy. 84, S of Blomquist St., E of Maple St.	15	Freshwater marsh (PEMW)*; industrial (UIM)
ASM-12	Redwood City: N of E. Bayshore Rd., S of Harbor Blvd.	8	Freshwater marsh (PEMW)*; barren (A/EBR)
ASM-13	E. Palo Alto: N of Kavanaugh Dr., W of Cooley Ave., S of SP Railroad	25	Freshwater marsh (PEMW)*; ruderal (A/ERV)
ASM-14	E. Palo Alto: S of Dumbarton Br. Hwy. 84, N of SP Railroad, end of Cooley Ave.	25	Freshwater marsh (PEMW)*; ruderal (A/ERV)
<u>SANTA CLARA COUNTY</u>			
ASC-1	Palo Alto: E of E. Bayshore Rd., adjacent to Matadero Creek/Mayfield Slough (Municipal Service Center)	<60	Diked salt marsh (E2EM7C1/2h) 40%, freshwater marsh (PEM5Ø) 50%, industrial (UIM) 10%
ASC-2	Mountain View: N of Garcia Ave./Charleston Rd., W of Stierlin Rd., adjacent to and part of Mountain View Shoreline Park (Permanente Creek)	200	Ruderal (URV) 50%, utilities (UTU) 40%, pasture (ARO) 10%
ASC-3	Mountain View: N of Charleston Rd., E of Stierlin Rd. (Stevens Creek)	150	Pasture (APF), adjacent to tidal creek (E1OWL)*
ASC-4	Mountain View: N of Charleston Rd., on E side of Stevens Creek, W of Moffett Field	<100	Ruderal (A/ERV), and diked salt marsh (E2EM7C1/2h)

Site No.	Location	Approximate Size (acres)	Use/Habitat**
ASC-5	Sunnyvale: N of 3rd Ave., W of Mathilda Ave., E of Moffett Field	<90	Freshwater marsh (PEMW)* and ruderal (A/ERV)
ASC-6	Sunnyvale: N of Caribbean Dr., E of Borregas Ave., S of Carl Rd., Sunnyvale Baylands Park	<10	Utilities (UTU)
ASC-7	Sunnyvale: Sunnyvale Baylands Park, N of Moffett Park Dr., E of Lawrence Expwy, S of Drainage Ditch	<20	Pasture (E2APh)
ASC-8	Sunnyvale: N of Hwy. 237, E of Sunnyvale Baylands Park, between Calabazas Creek and San Tomas Aquinas Creek	<40	Diked salt marsh (E2EM7C1/2h)
ASC-9	Sunnyvale: N of Hwy.101 along Calabazas Creek, between Mission College Blvd. and Patrick Henry Dr. in W. Valley College Campus	<20	Upland
ASC-10	Santa Clara: Along San Tomas Aquinas Creek between Tasman Dr. and Great America Parkway	<30	Agricultural
ASC-11	Santa Clara: Along San Tomas Aquinas Creek, E of Lafayette St., N of Gianera St.	200	Urban
ASC-12	Santa Clara: Along Hwy. 237, between Guadalupe River and San Tomas Aquinas Creek	<70	Salt marsh (E2EMP), utilities (UTU), ruderal (A/ERV), diked salt marsh (E2EM7C1/2h)
ASC-13	Alviso: S of Los Esteros Rd., N of Taylor St., E of School and Grand St.	<150	Ruderal (A/ERV), pasture (APF)
ASC-14	Alviso: N of Los Esteros Rd., SE of Grand Blvd. (near Environmental Ed. Center)	<40	Ruderal (A/ERV)
ASC-15	Milpitas: N of Hwy. 237, E of Zanker Rd.	<60	Row crops and orchards (ARO)
ASC-16+	Milpitas: W of Hwy. 17, N of Hwy. 237, E of Ranch Rd., adjacent to Coyote Creek	<60	Row crops and orchards (ARO)
ASC-17+	Milpitas: NE of intersection of Zanker Rd. and Center Rd., W of Boots Rd.	<60	Agriculture, adjacent to fresh-water marsh (PFOY, PEMY)*

Site No.	Location	Approximate Size (acres)	Use/Habitat**
ASC-18[+]	Milpitas: Along Coyote Creek, N of Sycamore Dr., S of Hwy. 237	<100	Agriculture
ASC-19[+]	Milpitas: N of Hwy. 237, W of Milpitas Blvd., E of WPRR tracks	< 60	Upland
ASC-20[+]	Milpitas: N of Hwy. 237, between Milpitas Blvd. and Berryessa Creek; near Milpitas Civic Center	< 25	Upland
ASC-21[+]	Milpitas: N of Hwy. 237, between Berryessa Creek and Hwy. 680	< 25	Upland
ASC-22[+]	Milpitas: Along WPRR tracks; S of Industrial Way	25	Upland
ASC-23[+]	Milpitas: NE of intersection of Abel St. and Capitol Ave., S of Curtis Ave. (Penitencia Creek)	30	Upland
ASC-24[+]	Milpitas: Along Coyote Creek between River Oaks Pkwy. and Mauvais Rd.	35	Upland
ASC-25[+]	San Jose: E of Hwy. 17, S of Rock Ave., W of Old Oakland Rd.	25	Upland
SOLANO COUNTY			
ASL-1	Vallejo: Between Hwy. 37-Sears Pt. Bridge and Mare Island Causeway, on E side of Mare Is. Straits	25	Subtidal (E1UBKL)*; salt marsh (E2EMN)
ASL-2	Vallejo: Between Lemon St. and Solano Ave., E of Sonoma Blvd. (Lake Dalwick)	30	Freshwater pond (PFLKY)*
ASL-3	Vallejo: W of Hwy. 80, E of 6th St., S of Lemon St.	25	Upland
ASL-4	Vallejo: N of Benicia Rd., between Rollingwood and Columbus Parkway	10	Gravel pit (AEX)

Site No.	Location	Approximate Size (acres)	Use/Habitat**
ASL-5	West of Hwy. 780, in Benicia, State Recreation Area, adjacent to Freeway	<50	Ruderal (A/ERV)
ASL-6	Benicia: Between 1st and E. 5th Sts., S of H St., near Benicia Marina	<50	Ruderal (A/ERV) 70%, residential (URH) 30%
<u>SONOMA COUNTY</u>			
ASN-1+	Petaluma: W of Hwy. 101, S of NW railroad, N of Petaluma River	35	Freshwater marsh (PEMW),* salt marsh (E2EMN)
ASN-2	Petaluma: S of Lakeville Hwy., SE of Casa Grande Ave., NW Frates Rd.	75	Freshwater marsh (PEMY)*< 10%, pasture (APF)

*Key to Use/Habitat designations: (based on National Wildlife Inventory Classification System)

- PEMW - freshwater marsh w/emergent vegetation: intermittently flooded/temporary
- PEMY - freshwater marsh w/emergent vegetation: saturated/semipermanent/seasonal
- PSSY - freshwater marsh w/shrub growth: saturated/semipermanent/seasonal
- PFLW - freshwater flat area: intermittently flooded/temporary
- PFLKY - freshwater flat area (artificially created): saturated/semipermanent/seasonal
- PKOY - freshwater marsh w/forested growth: saturated/semipermanent/seasonal
- POWZ - freshwater, open water: intermittently exposed/permanent
- POWKZ - freshwater, open water (artificially created): intermittently exposed/permenent
- E1OWL - subtidal, open water (unknown bottom)
- E1UBKL - subtidal, artificially created unconsolidated bottom
- E2EMP - intertidal, emergent, irregular

**Habitat designations as given in "Protection and Restoration of San Francisco Bay Fish and Wildlife Habitat" unless otherwide identified by *.

+Not shown on Regional Maps Appendix B

APPENDIX B

POTENTIAL SITES FOR WETLAND MANAGEMENT AND CREATION FOR URBAN RUNOFF TREATMENT

Map 1 - Richmond to Berkeley
Map 2 - Berkeley to Oakland
Map 3 - San Leandro, Hayward
Map 4 - Santa Clara and Southern Alameda Counties
Map 5 - Coyote Creek
Map 6 - Southern San Mateo County
Map 7 - Northern San Mateo County
Map 8 - San Francisco and Brisbane
Map 9 - Southern Marin County
Map 10 - Western San Pablo Bay
Map 11 - Petaluma River
Map 12 - Napa Marshes
Map 13 - Eastern San Pablo Bay
Map 14 - Carquinez Strait
Map 15 - Suisun Bay
Map 16 - Grizzly Bay
Map 17 - Honker Bay to Collinsville
Map 18 - Montezuma Slough

Map source: San Francisco Bay Conservation and Development Commission, December 1982

1 .5 0 MILE 1

1 .5 0 KILOMETER 1

NORTH

ABAG Regional Wetlands Program for Urban Runoff Treatment

MAP 1.

Richmond to Berkeley

Map source: San Francisco Bay Conservation and Development Commission, December 1982

ABAG Regional Wetlands Program for Urban Runoff Treatment

1 .5 0 MILE 1

1 .5 0 KILOMETER 1

NORTH

MAP 2.

Berkeley to Oakland

Map source: San Francisco Bay Conservation and Development Commission, December 1982

ABAG Regional Wetlands Program for Urban Runoff Treatment

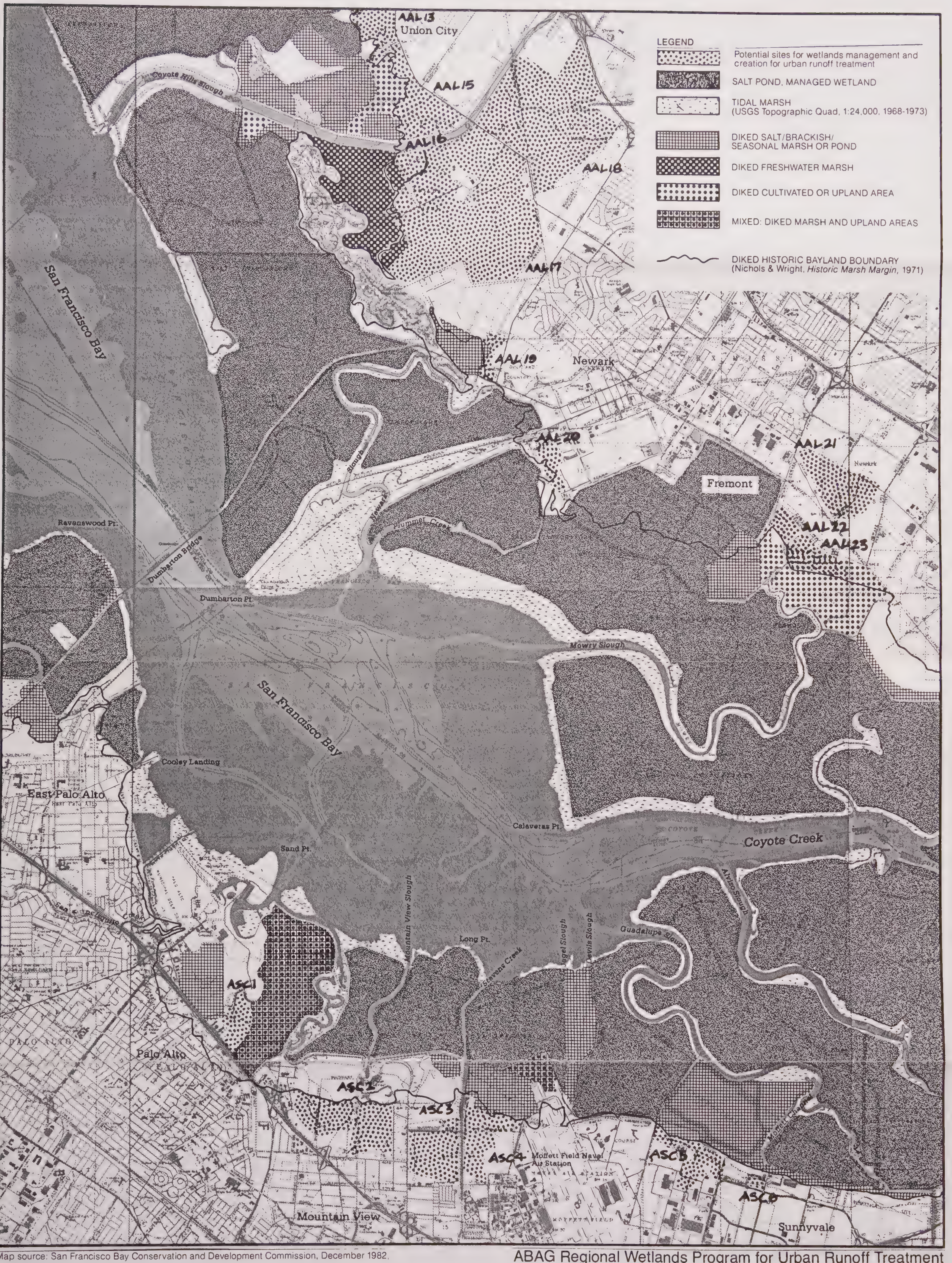
1 .5 0 MILE 1

1 .5 0 KILOMETER 1

NORTH

MAP 3.

San Leandro, Hayward



Map source: San Francisco Bay Conservation and Development Commission, December 1982.

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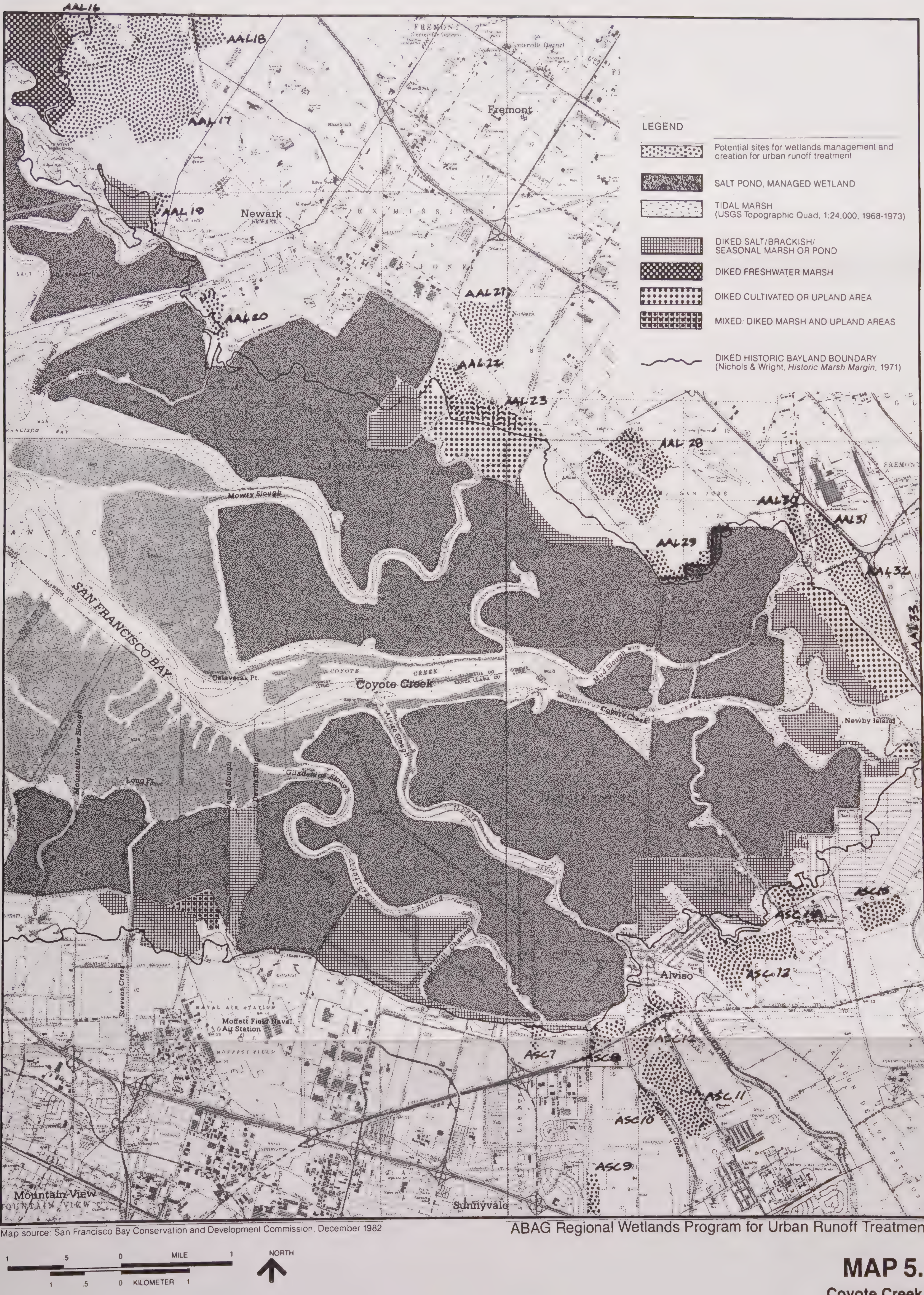
NORTH

ABAG Regional Wetlands Program for Urban Runoff Treatment

MAP 4.

Santa Clara and Southern Alameda Counties



Map source: San Francisco Bay Conservation and Development Commission, December 1982

ABAG Regional Wetlands Program for Urban Runoff Treatment

MAP 5.

Coyote Creek

Map source: San Francisco Bay Conservation and Development Commission, December 1982

ABAG Regional Wetlands Program for Urban Runoff Treatment

1 .5 0 MILE 1

1 .5 0 KILOMETER 1

NORTH

MAP 6.

Southern San Mateo County

Map source: San Francisco Bay Conservation and Development Commission, December 1982

ABAG Regional Wetlands Program for Urban Runoff Treatment

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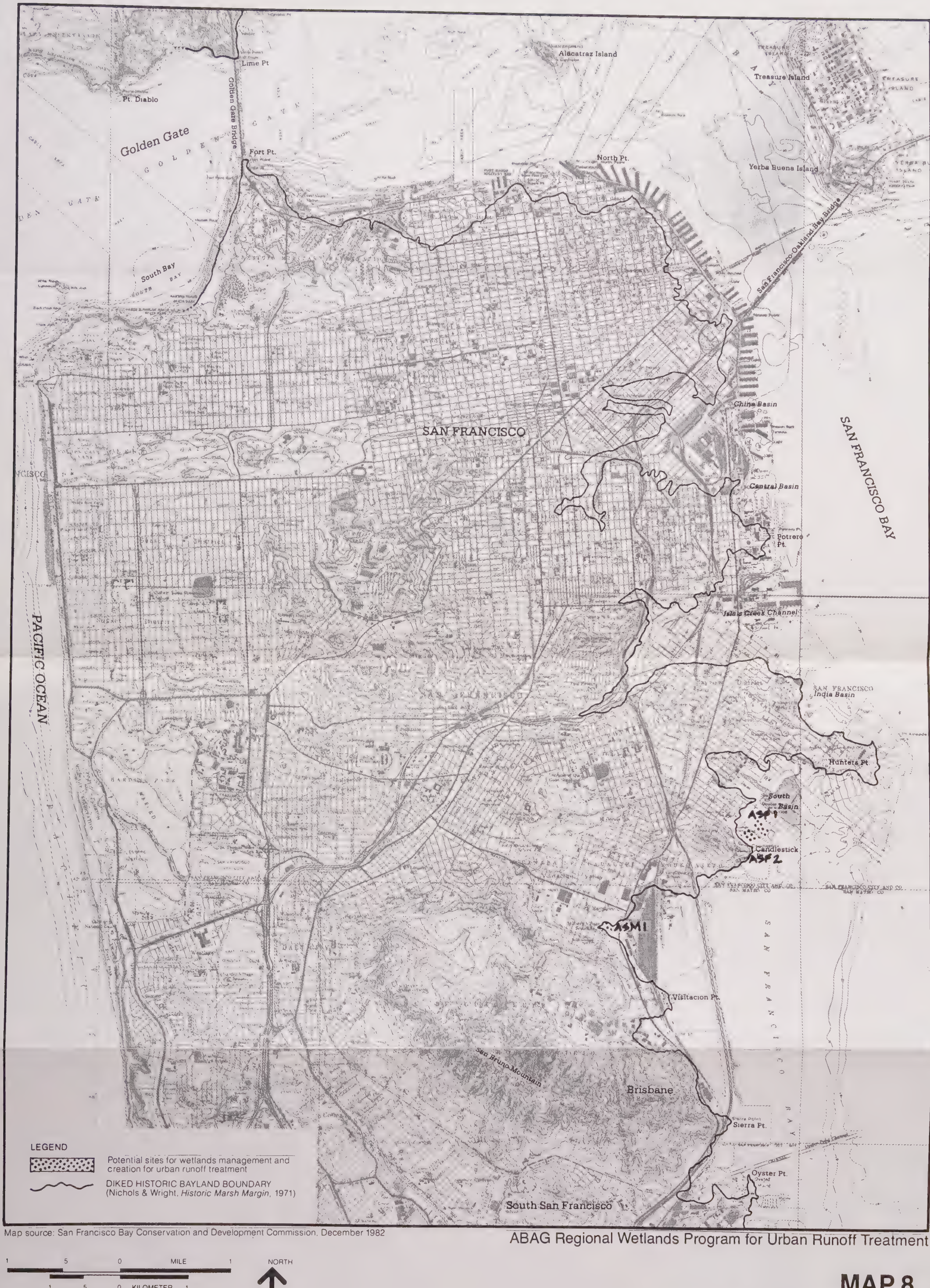
1 .5 0 KILOMETER 1

NORTH

MAP 7.
Northern San Mateo County



Map source: San Francisco Bay Conservation and Development Commission, December 1982

ABAG Regional Wetlands Program for Urban Runoff Treatment

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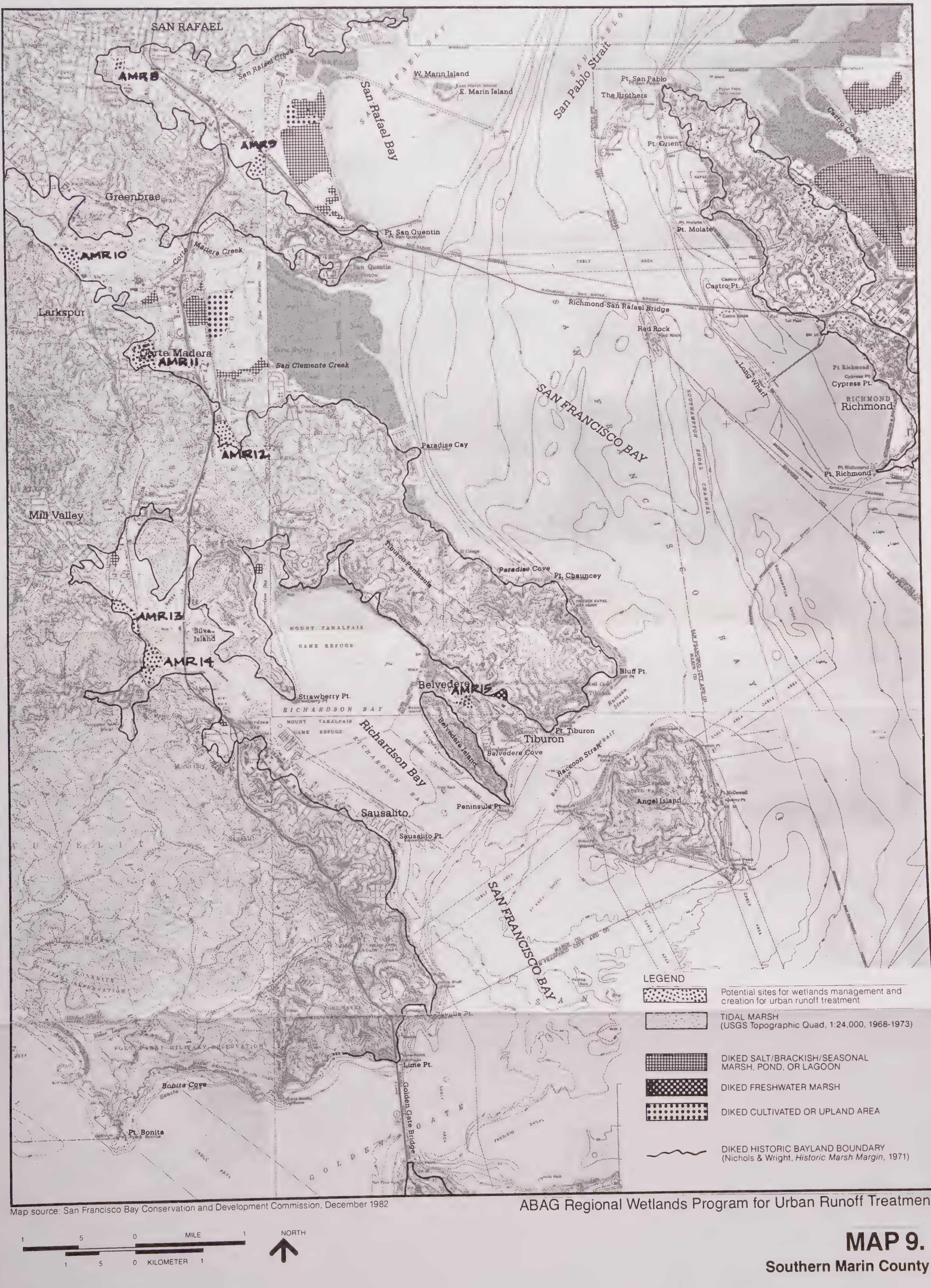
NORTH

MAP 8.

San Francisco and Brisbane



Map source: San Francisco Bay Conservation and Development Commission, December 1982

ABAG Regional Wetlands Program for Urban Runoff Treatment

MAP 9.
Southern Marin County

Map source: San Francisco Bay Conservation and Development Commission, December 1982

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1 .5 0 KILOMETER 1

NORTH

ABAG Regional Wetlands Program for Urban Runoff Treatment

MAP 10.

Western San Pablo Bay

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